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Evaluation of Environmental-Control Technologies for Commercial Nuclear- Fuel-Conversion (UF_6) Facilities

B. L. Perkins

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CONTENTS

ABSTRACT	1
CHAPTER I — INTRODUCTION	i
A. Background Information	1
B. Report Objectives	2
C. Framework of Study	2
CHAPTER II — ALLIED CHEMICAL—METROPOLIS WORKS	2
A. Background Information	2
B. Normal Processes Having Waste and Effluent Streams	2
1. Introduction	2
2. Receiving and Sampling	4
3. Sodium Removal (Pretreatment)	4
4. Feed Preparation	6
5. Reduction	7
6. Hydrofluorination	7
7. Fluorination	11
8. Fluorine Production	13
9. Uranium Recovery	13
10. Cylinder Wash	15
11. Sludge Dryer	15
12. Storage and Handling	15
13. Liquid Treatment	15
14. Summary	17
C. Available Data for Routine Waste/Effluent Releases, Storage, and Disposal	17
1. Air	17
2. Water	22
3. Sludges	22
4. Solid, Nonsludge Wastes	22
D. Inadvertent Releases Involving Wastes and Effluents	26
1. Operational	26
2. Releases from Pond Operations	26
3. Releases Caused by Rupture of Ducts and Piping Carrying Waste Streams	26
4. Failure of Effluent and Waste Treatment Equipment	26
5. Transportation	29
E. Long-Term Releases	29
F. Recommendations	30
REFERENCES	30
CHAPTER III — KERR-McGEE NUCLEAR CORPORATION—SEQUOYAH	31
A. Background	31
B. Process Description	31
1. Introduction	31
2. Receiving and Sampling	31
3. Digestion	31
4. Solvent Extraction and Acid Scrubbing	33
5. Stripping and Solvent Purification	33

6. Scrubbing, Decanting, and Concentration	33
7. Denitration and Feed Preparation	35
8. Reduction	35
9. Hydrofluorination	36
10. Fluorination	38
11. Fluorine Production	40
12. Miscellaneous Wastes and Effluents	40
13. Miscellaneous Digester	41
14. UF ₆ Cylinder Wash	41
15. Chemical Inventories	41
16. Summary of Discharges	41
C. Available Data for Routine Releases, Disposal, and Treatment of Wastes	41
1. Airborne Effluents	41
2. Water	42
3. Heat Load Estimates	46
4. Ponds and Sludges	46
a. Raffinate Ponds	46
b. Fluoride Treatment Ponds	54
5. Solid Nonsludge Wastes	55
D. Inadvertent Releases Involving Wastes and Effluents	56
1. Operational	56
2. Releases from Pond Operations	56
3. Releases Caused by Rupture of Ducts and Piping Carrying Process Streams	57
4. Failure of Effluent and Waste Treatment Equipment	57
5. Transportation	57
E. Long-Term Releases	57
F. Recommendations	57
REFERENCES	58
CHAPTER IV — CONCLUSIONS AND RECOMMENDATIONS	58
A. Effluent/Waste Characterization	58
B. Plant Circuit Design and Waste Treatment	58
C. Recommendations for Monitoring	59
D. Recommendations for Studies of Long-Term Aspects	60
APPENDIX	61

EVALUATION OF ENVIRONMENTAL CONTROL TECHNOLOGIES FOR COMMERCIAL NUCLEAR FUEL CONVERSION (UF₆) FACILITIES

by

B. L. Perkins

ABSTRACT

At present in the United States, there are two commercial conversion facilities. These facilities process uranium concentrate into UF₆ for shipment to the enrichment facilities. One conversion facility uses a "dry" hydrofluor process, whereas the other facility uses a process known as the "wet solvent extraction-fluorination" process. Because of the different processes used in the two plants, waste characteristics, quantities, and treatment practices differ at each facility. Wastes and effluent streams contain impurities found in the concentrate (such as uranium daughters, vanadium, molybdenum, selenium, arsenic, and ammonia) and process chemicals used in the circuit (including fluorine, nitrogen, and hydrogen), as well as small quantities of uranium.

Studies of suitable disposal options for the solid wastes and sludges generated at the facilities and the long-term effects of emissions to the ambient environment are needed.

CHAPTER I

INTRODUCTION

A. Background Information

Uranium conversion facilities are a necessary component in the production of uranium fuel for commercial light water reactors. In the fuel production process, the uranium is originally mined (or recovered by *in situ* processes or as a by-product) from uranium-bearing host material. Except in *in situ* or by-product recovery processes, the uranium in the mined material is usually concentrated in mills located near the mines. This material, known as concentrate or "yellowcake," contains approximately 70-75% uranium and various impurities (depending on mill circuit and original concentrations of impurities in the ore).

The concentrate from the mills and concentrate (or slurry) from *in situ* and by-product recovery processes is sent to conversion facilities, where the uranium in the feed is converted into gaseous (at elevated temperatures) UF₆. (This conversion to a gaseous compound is done because of the necessity to increase slightly the concentration of the ²³⁵U isotope relative to the ²³⁸U isotope. The only presently proven techniques for performing this "enrichment" use gases for this process.)

The UF₆ product from conversion is sent to the enrichment facilities for the desired increase in the ²³⁵U isotope concentration.

At nuclear fuel fabrication facilities, the enriched UF₆ is converted to uranium dioxide powder. The powder is then densified/pelletized into fuel pellets. The pellets are loaded into long rods; the rods are assembled into fuel "bundles" and shipped to commercial nuclear reactors for use as reactor fuel.

At present in the United States, there are two privately operated uranium conversion facilities: the Metropolis Works operated by Allied Chemical and the Sequoyah facility operated by Kerr-McGee. The Allied facility uses a "dry" conversion process circuit, whereas the Kerr-McGee facility uses a "wet" conversion process. These facilities will be discussed in detail in the next two chapters.

B. Report Objectives

As part of the evaluation of effluents/wastes relating to the commercial nuclear fuel cycle, the objectives of this report were to determine the process discharge streams produced by the UF_6 conversion facilities, to determine how these streams are presently treated, to collect any publically available emission and monitoring data, to identify the final fate of these wastes, and to assess the adequacy of present waste treatment/disposal techniques and available data.

C. Framework of Study

To determine the origin, quantity, and types of waste streams generated by the wet and dry processes, a complete block flow diagram for each facility was constructed using material published in environmental reports and similar sources of information. These flow diagrams were then used to try to identify inputs and outputs and thus the origin and composition of each type of waste stream. Next, the treatment techniques for each stream were identified and data on waste types, quantities, and types of disposal collected. Once a draft report of the description and waste data for a facility was complete, the report was sent to the company operating the facility for corrections. Each study was then used as the basis for specific recommendations.

CHAPTER II

ALLIED CHEMICAL—METROPOLIS WORKS

A. Background Information

From 1958-1964, Allied Chemical operated the Metropolis, Illinois UF_6 production facility to supply feed for the Paducah Gaseous Diffusion plant under an Atomic Energy Commission (AEC) contract. In February 1968, to meet the demands of the commercial power reactor industry, the plant resumed operation, and the

UF_6 product has since been shipped to all three Department of Energy (DOE) operated enrichment facilities (Safety Evaluation Report—SER).

At present, Allied Chemical has processed, from concentrate produced internationally, over 200 million pounds of uranium. The current throughput capability is approximately 14 000 tons of uranium annually (Concentrate Sampling—CS).

Purities of 99.99% UF_6 are consistently achieved at the facility; hence, the product exceeds all current enrichment product standards and will most likely be able to meet any upgraded standards set in the future (UF_6 Conversion— UF_6 -C). Thus, plant lifetime is expected to be at least another 30 years (Order to Modify License, Amendment No. 4—OML).

If concentrate is to be shipped elsewhere for conversion, Allied offers a uranium concentrate sampling service (CS). Allied Chemical also offers its customers an extensive UF_6 storage service (Custom UF_6 Storage—C UF_6 S).

In addition to UF_6 production and associated activities, Allied has the capacity to manufacture approximately 30 000 lb/wk of liquid fluorine, 1200 ton/yr of sulfur hexafluoride, 2500 lb/wk of antimony pentafluoride, and 10 000 lb/wk of iodine pentafluoride at the Metropolis Works (Environmental Impact Appraisal 1977—EIA 1977). The Metropolis Works is the free world's largest producer of both liquid fluorine and sulfur hexafluoride (Hosey and Hill 1980; Kostick and De-Fillippo 1980). Figure II-1 indicates a plot plan of the facility

The Metropolis Works is located on an 862.3-acre tract bounded on the southwest by the Ohio River. A section of the southeast property boundary is contiguous with the town limits of Metropolis (EIA 1977).

The area is semirural. Close industrial sites include the AEP coal blending plant, the Shawnee Steam Plant, and the Paducah gaseous diffusion plant (EIA 1977). Approximately 450 people are employed at the facility.

Further data on land use, population, geology, hydrology, and other background characteristics may be obtained from the Environmental Impact Appraisal.

B. Normal Processes Having Waste and Effluent Streams

1. Introduction

The Allied facility uses the fluoride volatility process to produce UF_6 from uranium concentrates. The facility does not accept uranium slurries.

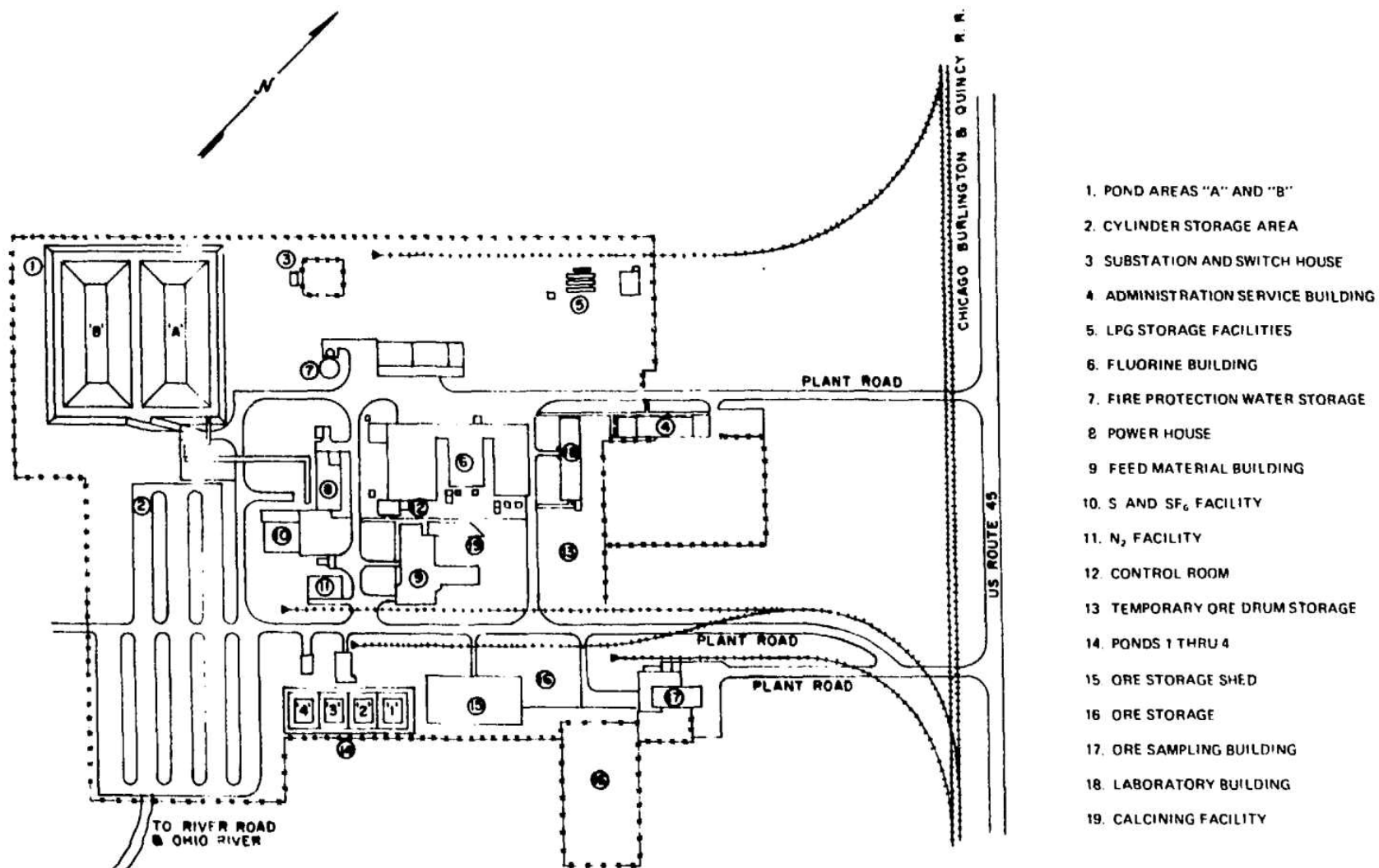


Fig. II-1. Plot plan of the Metropolis site.

When the 55-gallon-drummed concentrate is received, it is weighed, sampled, and analyzed for moisture content. After feed preparation, mechanically sized particles (U_3O_8) are reacted with hot cracked ammonia to form uranium dioxide (UO_2). This compound is in turn reacted with vaporized anhydrous hydrofluoric acid to form uranium tetrafluoride (UF_4) or green salt. Next, the green salt is combined at high temperature in a fluidized bed with gaseous fluorine to form the gas UF_6 . Finally, the UF_6 off-gas stream is further purified by condensation and fractional distillation (EIA 1977).

Each of these steps, with the resulting waste and effluent streams, is discussed in detail in the following sections.

2. Receiving and Sampling

The concentrate is received into the plant in 55-gallon drums. The drums are stored outside on specially constructed pads designed to avoid ground water contamination. Rain water from the pad area drains to central collection sumps and is then pumped to uranium spill control ponds* (EIA 1977).

Drums are weighed, and a falling stream method is used to obtain a representative sample (CS). The samples are taken by customer lot to ensure that each customer's concentrate is recorded adequately. The airborne dusts generated in the sampling process are removed through the use of two baghouses in series, which discharge through the 1-3 stack (EIA 1977). Empty drums are aircleaned, with the dust discharge being collected in two baghouses and the cleaned discharge exiting through the 1-11 stack. Details of receiving, sampling, and drum cleaning are given in Figs. II-2 and II-3. All residues from the collection devices are combined with the other concentrates of the customer and drummed until further processing (EIA 1977).

If the samples indicate that the concentrates contain a high percentage of sodium (because of the particular mill circuit used to produce the concentrate), the concentrates are sent to the sodium-removal facility before they are received into the main processing circuit (EIA 1977).

3. Sodium Removal (Pretreatment)

Because sodium forms a compound that causes caking and sintering in the fluorination fluid beds, any incoming uranium concentrates containing sodium and all the

uranium concentrates produced by the uranium recovery sections of the UF_6 facility must first have the sodium or potassium removed before they can be processed (Sears et al. 1977). These concentrates are treated by reaction with a solution of $(NH_4)_2SO_4$ in four counter-current vessels (Fig. II-4). The chemical reaction is



The liquid effluent contains the excess $(NH_4)_2SO_4$, Na_2SO_4 , K_2SO_4 , and uranium and small quantities of ^{226}Ra , ^{230}Th , selenium, molybdenum, and other trace impurities. This effluent is sent to the two uranium spill control ponds* (OML). Uranium contaminated storm water is also discharged to these ponds. The sludges are allowed to settle, and the decantate is discharged to the main discharge outfall for the plant. There is a sampling station for measuring flow rates (approximately 40 gpm) and obtaining a 24-h composite sample located at a point before the discharge is combined with other discharges at the main discharge outfall. When the minimum freeboard is reached (approximately 2 ft) on a pond, the pond is dredged and the sludge is sent to the pond sludge calciner

55 gallon drums from mills

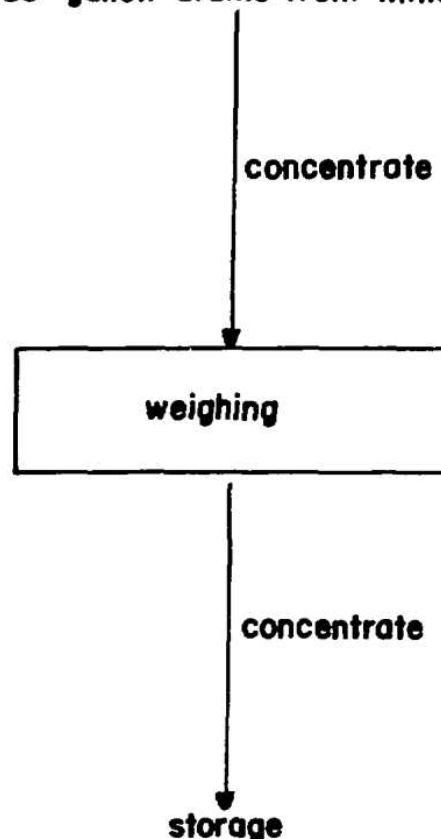


Fig. II-2. Receiving.

*See Fig. II-14.

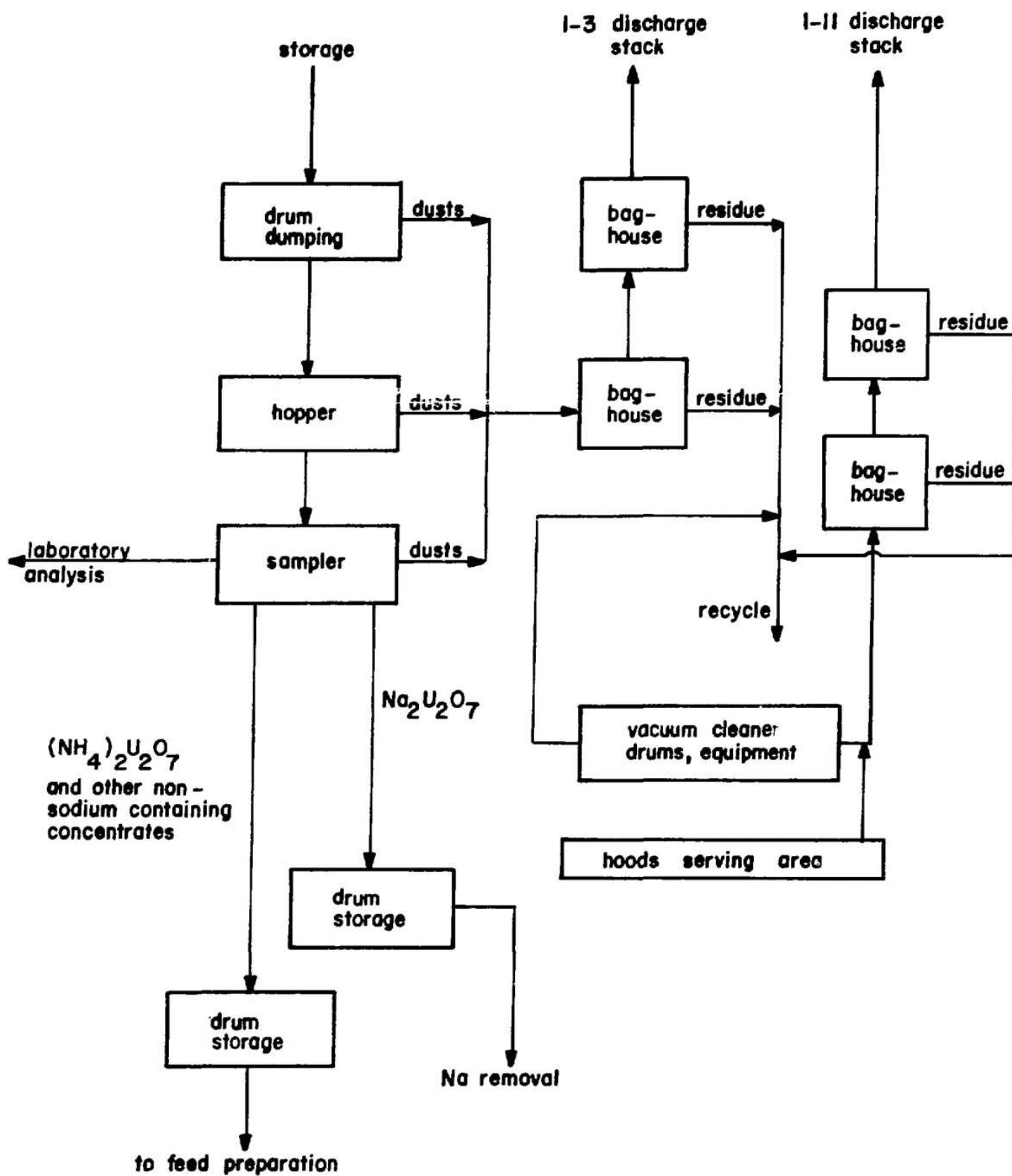


Fig. II-3. Sampling and cleaning.

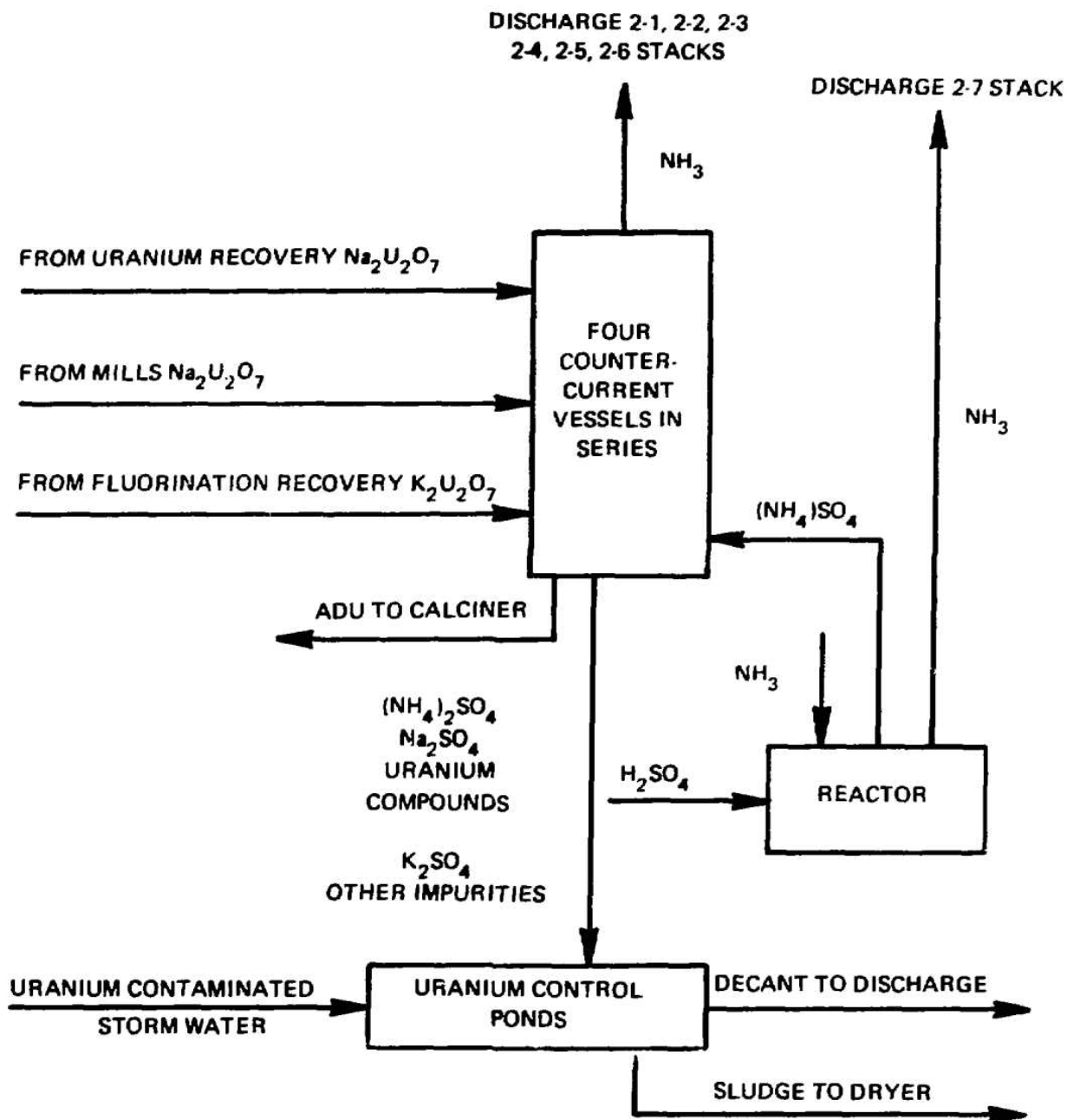


Fig. II-4. Pretreatment (sodium removal).

(which is discussed in Sec. B.11) (OML). Pond liners are inspected and repaired at this time. In addition, all pond liners are underlain by a gravel layer that allows any seepage to drain to a leak detection sump.*

During pretreatment, ammonium sulfate reacts with hydroxide and possibly carbonate impurities in the concentrate to evolve ammonia (Sears et al. 1977). This ammonia is released through stacks 2-1, 2-2, 2-3, 2-4, 2-5, and 2-6 at the facility (EIA 1977).

The $(\text{NH}_4)_2\text{U}_2\text{O}_7$ (ADU) is removed from solution in the last reaction vessel and is sent to the main feed preparation section of the plant.

The $(\text{NH}_4)_2\text{SO}_4$ is produced on-site (Fig. II-4). Off-gases from the reactor vessel, which include NH_3 , are vented through the 2-7 stack (EIA 1977).

4. Feed Preparation

In the feed preparation circuit, sodium-free uranium concentrate, either from the pretreatment section or from the sampling section, is first fed into a calciner where

*This information provided by Dale Declue, State of Illinois.

water and ammonia are removed (see Fig. II-5). The off-gases containing ammonia, sulfur dioxide, uranium, and contaminant particulates pass through two baghouses in series. Particulates recovered by blowback of the baghouses are collected and sent back into the blending feed stream (EIA 1977).

Ammonia, sulfur dioxide, and any uranium dusts not collected by the baghouse are emitted from the 1-1 stack.* The ore calciner heat boiler, having a maximum heat rate of 8×10^6 BTU/h, uses natural gas as the fuel, and NO_x and CO_2 are emitted from the 1-9 stack (EIA 1977).

The calcined material is blended and then agglomerated, dried, crushed, and sized before being sent to the reduction circuit (Fig. II-5). Wet off-gas streams join the off-gases from the calciner, whereas dry off-gases pass through two baghouses in series before discharge through the 1-2 stack (EIA 1977). Material collected by the dry stream baghouse is fed into the blending feed stream. The heater for the dryer is fired by natural gas (6×10^6 BTU/h), and off-gases discharge through the 1-8 stack (EIA 1977).

5. Reduction

In the reduction circuit, Allied operates two trains in parallel, both having the same basic design. The U_3O_8 from the feed preparation circuit is fed into the reductor vessel where hot cracked ammonia (N_2 and H_2) and additional nitrogen mix with the feed to form a fluidized bed. The U_3O_8 is reduced to UO_2 , which is withdrawn from the bottom of the bed. Off-gases from the reactor include H_2 , N_2 , H_2S , AsH_3 , vaporized S, SeH_2 , and particulates composed of UO_2 , unreacted U_3O_8 , and reduced compounds of impurities originally in the concentrate (Fig. II-6) (Sears et al. 1977). (Most of the sulfur originally in the concentrate is volatilized in the reduction off-gases.)

The off-gases pass through two porous metal filters in series, a sulfur condenser, and an incinerator. Residual gases discharge through the 1-48 stack (EIA 1977).

Elemental sulfur from the sulfur condenser is stored on-site.

Particulates collected by cleaning the filters are sent to the uranium recovery section.

Off-gases from the oxide vacuum cleaner are sent through a cyclone and two baghouses in series before discharge through the 1-4 stack (Fig. II-6) (EIA 1977).

*See Fig. II-5 and Table II-3.

Residues from these collection devices are sent to the uranium recovery section.

The emergency discharge vents on the two trains discharge through the 1-15 and 1-16 stacks, respectively (EIA 1977).

The off-gases from the ammonia dissociator (Fig. II-6) discharge through the 1-45 vent (EIA 1977).

6. Hydrofluorination

Again in the hydrofluorination circuit, two trains in parallel are in use. The UO_2 from reduction is fed into two reactor vessels in series, which use vaporized hydrofluoric acid and N_2 to fluidize the UO_2 and permit HF to react with the material to form UF_4 (Fig. II-7). The off-gases contain the excess HF needed to give good conversion to UF_4 (10% excess or more), volatile SiF_4 , BF_3 , and some of the molybdenum and vanadium (which were present as impurities in the concentrate) as volatile fluorides and oxyfluorides, and any remaining sulfur as H_2S (Sears et al. 1977). These gases first pass through two sets of two porous carbon filters per set, where the unreacted UO_2 particles, entrained UF_4 particles, and any other particulate matter are removed. The gases then pass through two venturi water scrubbers, where the H_2O in the off-gases condenses, and finally through a venturi KOH scrubber and a packed tower using KOH scrubbing liquid (EIA 1977).

The residue from the cleaned carbon filters is sent to uranium recovery. Liquid coming from the venturi water scrubbers contains hydrofluoric acid and is sent to the acid neutralization treatment plant, where lime is added to precipitate the fluorine as CaF_2 (Fig. II-7. Also see Fig. II-14.) (Hosey and Hill 1980). The uranium content of this stream is reported to average less than 5 ppm (OML). Silicon, boron, and some molybdenum and vanadium, which were originally in the concentrate, are expected to be in the sludge. The liquid from the KOH venturi and packed tower is sent to the liquid treatment systems. Further details on the KOH regeneration system are given in Sec. B.13.

The vacuum cleaning off-gases from the cleaning activities necessary in the hydrofluorination section are routed through a cyclone and two baghouses before discharge through the 1-7 stack. Residues from the dust collectors are sent to the uranium recovery section.

The upper and lower vent spill dampers discharge for each train through the 1-18, 1-20, 1-17, and 1-19 stacks, respectively (Fig. II-7) (EIA 1977).

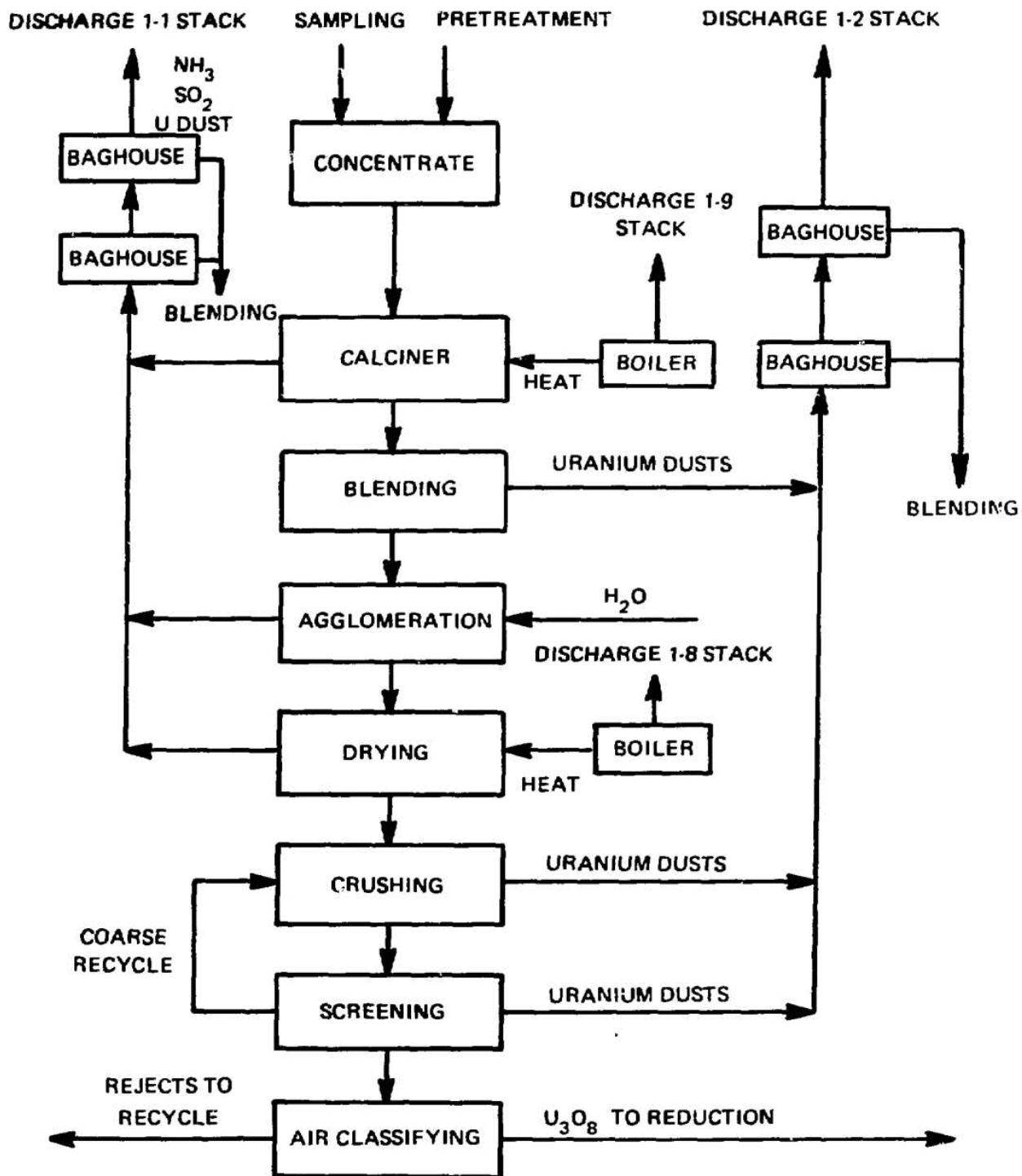


Fig. II-5. Feed preparation.

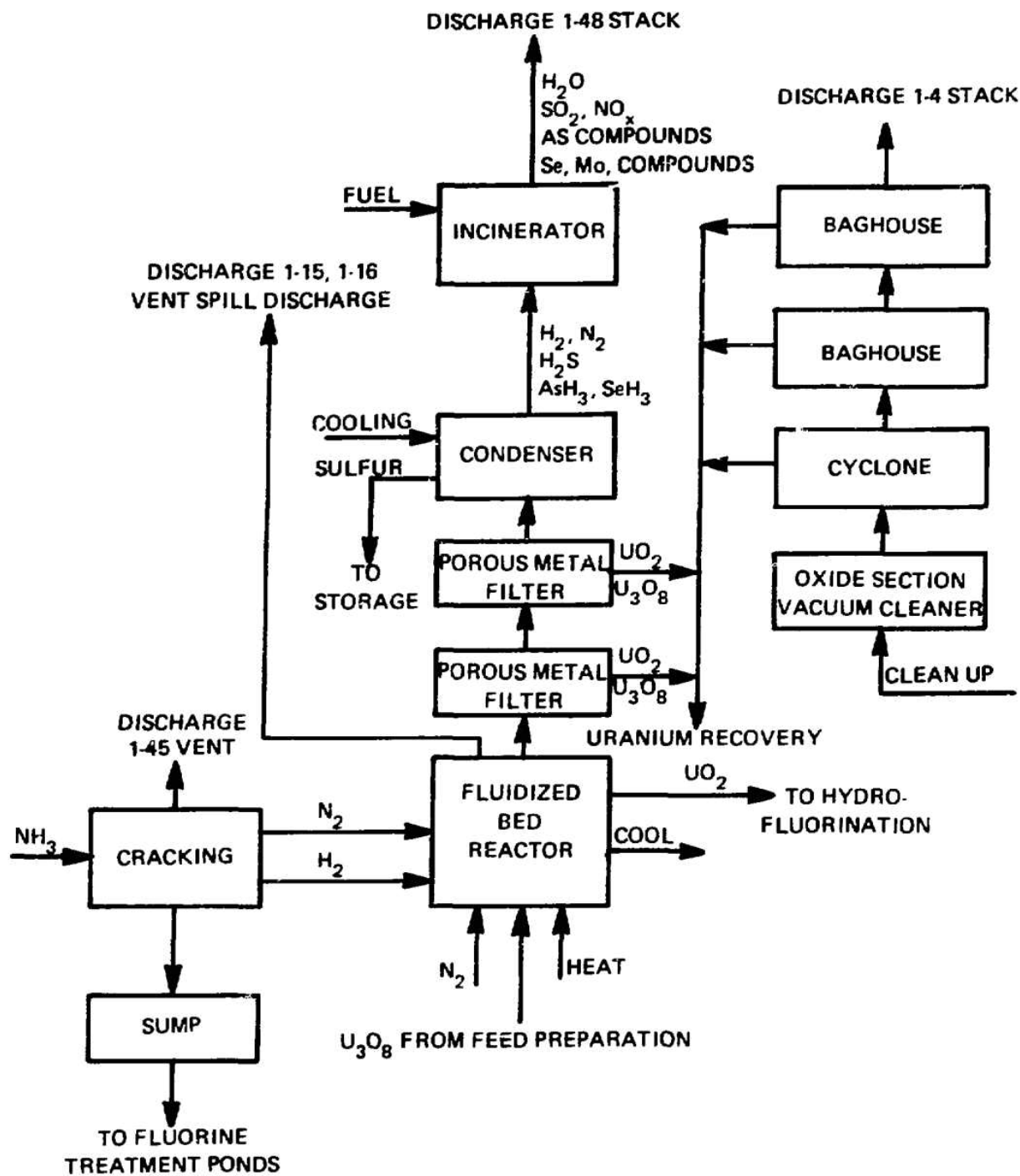


Fig. II-6. Reduction (two trains A and B).

Sludge from the HF vaporized (Fig. II-7) is sent to the acid treatment plant.

7. Fluorination

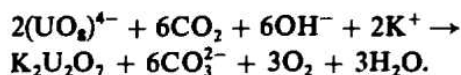
The green salt, UF_4 , produced in the hydrofluorination process is fed into one of two fluid bed reactors used in parallel (Fig. II-8) (EIA 1977). Again, Allied uses two trains at the works.

The bed material is CaF_2 and unreacted UF_4 . The vessels are operated at temperatures of approximately $1000^\circ F$, and good temperature control is required. Fluorine, F_2 , from an on-site fluorine production facility (Fig. II-9) is introduced into the reactor vessels to convert the UF_4 into gaseous UF_6 (EIA 1977).

The off-gases, including UF_6 , F_2 , HF, unreacted UF_4 , and other particulates, and volatilized impurities including VF_3 , VOF_3 , MoF_6 , and low concentrations of bismuth, phosphorus, antimony, and chromium fluorides, are first cooled before passing through two sets of sintered nickel filters, each containing two filters (EIA 1977). The material recovered as the filters are cleaned is stored and then sent to the uranium recovery section.

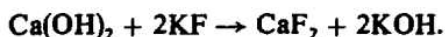
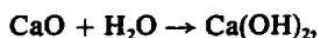
The stream exiting from the filters has the UF_6 removed by condensation in a set of three cold traps used in series (Fig. II-8). Any uncondensed UF_6 , F_2 , HF, and other volatiles passing from the cold traps are removed from the gas stream by a KOH spray tower, a KOH packed tower, and finally a KOH coke box. The final cleaned gases are emitted from the 1-13 and 1-14 stacks, respectively, for each train (EIA 1977).

Carbon dioxide in the spent scrubber liquor reacts with the uranium and potassium (Sears et al. 1977) as follows.



The $K_2U_2O_7$ is settled from the KOH solution and sent to the pretreatment facility (Fig. II-4).

Decantate from the uranium settling section is sent to the KOH regeneration system as indicated previously. The reactions are (Sears et al. 1977)



The KOH is then sent back to the scrubbing system (Fig. II-8). In addition to CaF_2 , compounds of uranium,

vanadium, and molybdenum, trace quantities of compounds of silica, carbon, sulfur, and other trace contaminants are expected to be in the sludge (Sears et al. 1977). The KOH treatment system is described more fully in Sec. B.13.

The condensed material in the three cold traps in series is melted and drained to the still feed tanks. Entrained HF is vaporized during melting and passes to the off-gas system (Sears et al. 1977).

From the still feed tanks, the liquid is fed to a low-temperature boiler bubble cap column in which the impurities, such as VF_3 , MoF_6 , SiF_4 , CF_4 , SF_6 , and VOF_3 are volatilized and exit from the top of the column. The VOF_3 impurity is condensed in the VOF_3 condenser. The VOF_3 is cleaned from the condenser and stored. Impurities not removed in the condenser are fed back to the system just before the cold traps (Sears et al. 1977).

The liquid UF_6 passes from the low boiler column into the bubble cap, high boiler column (Fig. II-8). In this column, the UF_6 is volatilized and exits from the top of the column. Nonvolatilized impurities are removed from the bottom of the column and stored (EIA 1977).

The gaseous UF_6 from the column is condensed in two cold traps operated in series. The UF_6 is transferred to the UF_6 shipping cylinders by melting the UF_6 and allowing the material to drain into the cylinders.

Because impurities build up on the recycled CaF_2 bed material used in the fluorination reactors, part of the bed material must be withdrawn periodically. This "ash," along with the fluorination-cleaning filter residue, is drummed and stored for a minimum of 6 months to permit the uranium daughters ^{234}Th and ^{234m}Pa to decay. The ash is then sent to the uranium recovery section. A total quantity of ash of about 0.1 ton of ash per ton of uranium processed is produced, and it contains approximately 1.8% of the total uranium processed and most of the uranium daughters originally present in the concentrate (Sears et al. 1977).

The dusts produced by withdrawing bed material from the reactors are passed through a cyclone and two baghouses in series before discharge through the 1-12 stack (EIA 1977). The ash vacuum cleaner systems also discharge from this stack. Residue from cleaning these particulate removal devices is treated similarly to the spent bed material.

Over-pressure releases, etc., discharge through the 1-21 and 1-22 spill damper stacks (EIA 1977).

The feed preparation, reduction, hydrofluorination, and fluorination circuits are all located in the feed

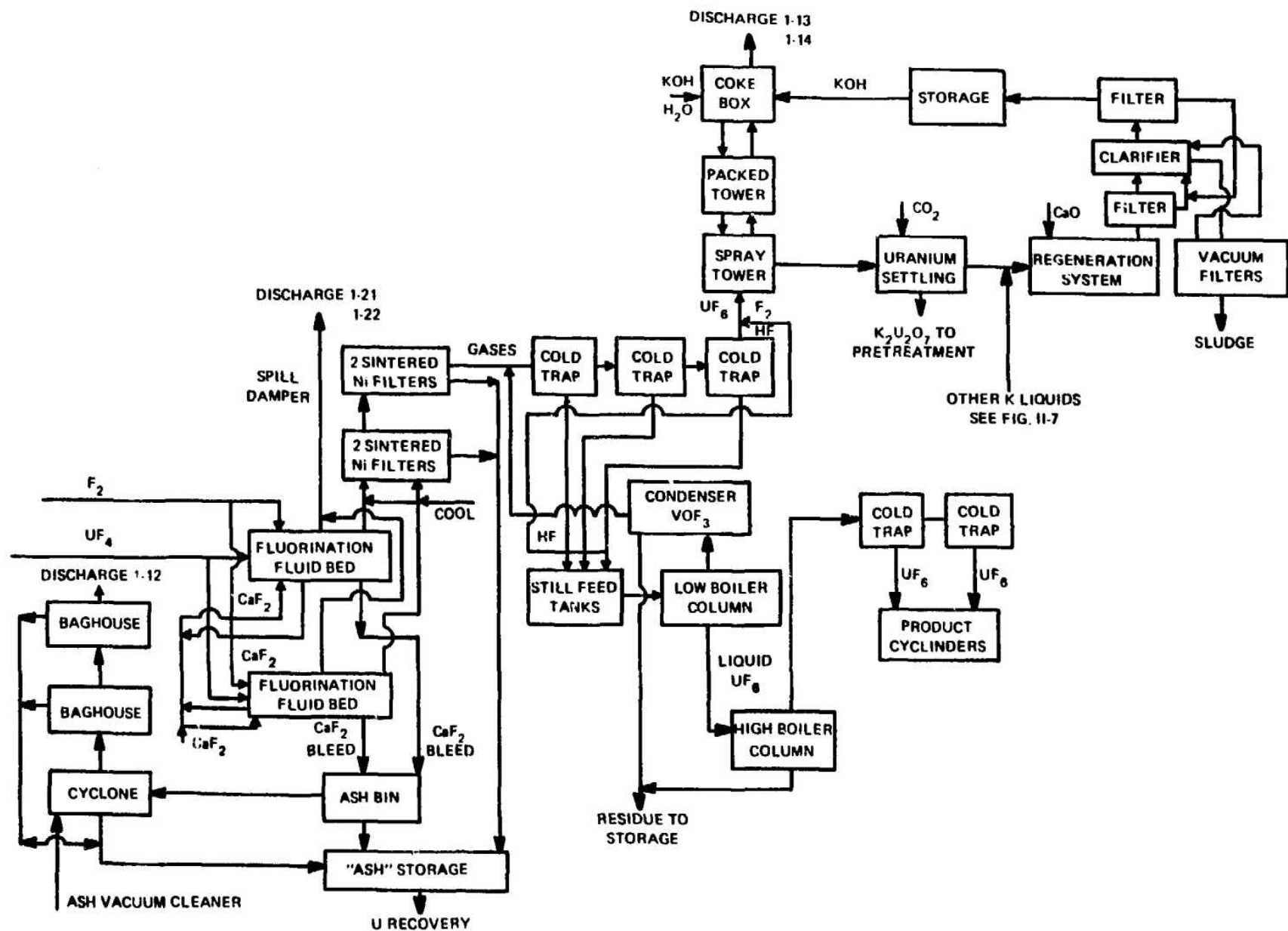


Fig. II-8. Fluorination (two trains A and B).

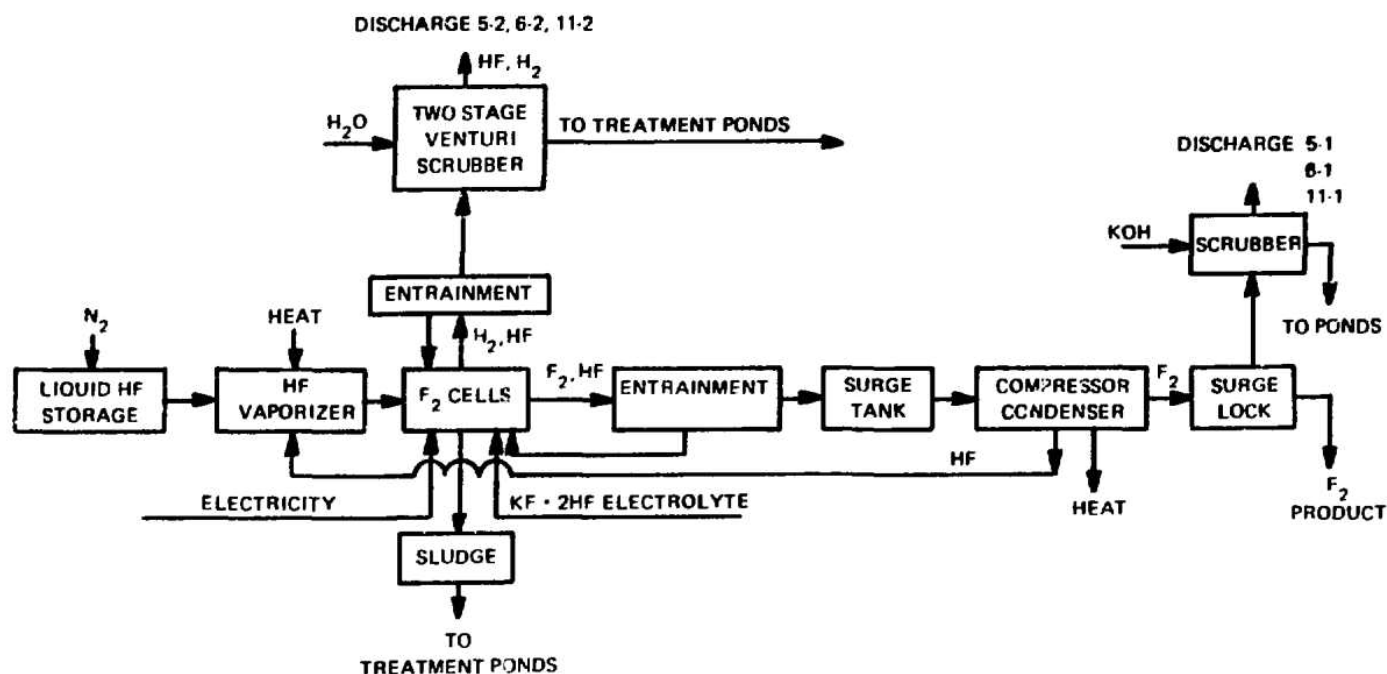


Fig. 11-9. Fluorine production.

material building. This building has a complete air changeout approximately once every 5 minutes. The exhausts are through the 1-27, 1-28, 1-29, 1-30, 1-31, 1-32, 1-33, 1-34, 1-35, 1-36, 1-37, 1-38, and 1-39 stacks (EIA 1977).

Washdown of the feed materials building is pumped from collection sumps into the uranium recovery ponds.

The transfer lock to fluorination discharges through two baghouses to the 1-10 stack (Fig. II-7) (EIA 1977). Again, dust collection residue is sent to uranium recovery.

8. Fluorine Production

Fluorine is produced on-site by electrolysis (Fig. II-9) using hydrogen fluoride as the raw material. This section is the largest free-world liquid-fluorine-producing operation in existence (Hosey and Hill 1980).

The sludge from clean-up of the cells joins other sludge in the CaF_2 precipitation ponds. Off-gases and waste gases are scrubbed, and the scrubber liquids containing fluoride compounds are sent to the acid neutralization treatment plant (EIA 1977).

The cleaned gases exit from the stacks noted in Fig. II-9 (EIA 1977).

9. Uranium Recovery

There are several sources of uranium-containing wastes produced by the facility, and it is desirable to recover the uranium from these wastes. Thus, uranium-containing dried sludges, spent bed material, filter residue, and various scraps and dusts are sent to the uranium recovery circuit (Fig. II-10).

Off-gases from storage before processing vent through the 3-1 stack (EIA 1977). The main contaminants in the stack off-gases should be radon and radon daughters, if the radium originally in the concentrate feed goes into the ash (as was assumed in the previous section).

The material from storage is first dumped and ground. Dusts from this operation are recovered in a baghouse, and the clean gases exit from the 3-2 stack (EIA 1977).

The finely ground material is leached, using a sodium carbonate solution to solubilize the uranium as the tricarbonate complex. Off-gases from the leaching tanks exit through the 3-3 and 3-4 stacks (EIA 1977).

After leaching, the pregnant solution is filtered. Lime is added to aid in precipitation of any fluoride, and the solution is again filtered. Sludge from the filters is dried. Off-gases from the dryer pass through the dumping and grinding off-gas baghouse.

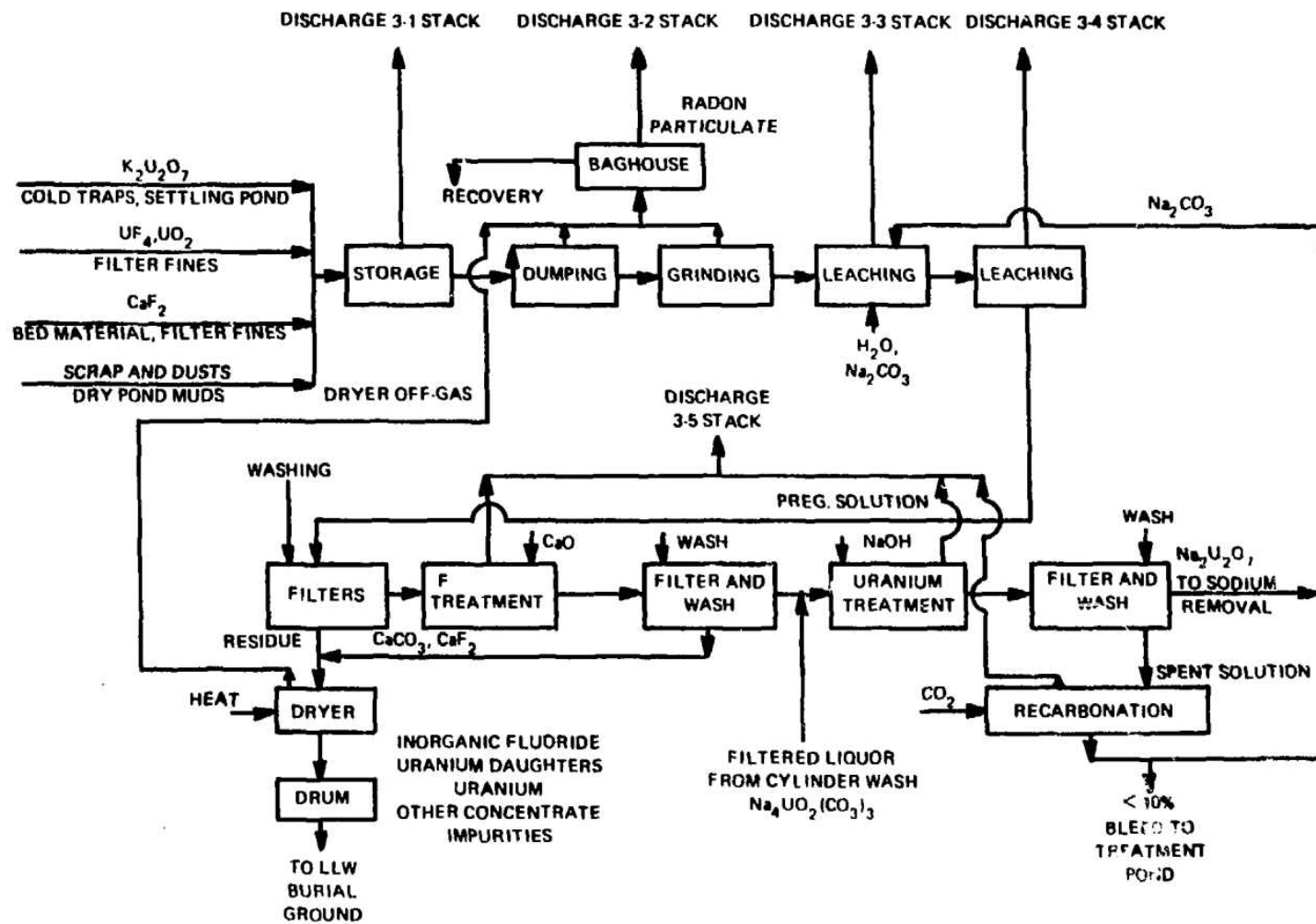


Fig. 11-10. Uranium recovery.

The dried sludge probably contains all the nondecayed uranium daughters, some residual uranium, and some fluoride compounds. This sludge is drummed and sent to a licensed radioactive waste disposal facility (SER). Approximately 1500 tons of this waste, containing a maximum of 46.9 Ci, is produced yearly (EIA 1977).

The uranium is precipitated from the solution using NaOH. The uranium is filtered and washed and then sent to the sodium removal section. Off-gases from the precipitation vessels are emitted from the 3-5 stack.

Bleed from the leaching circuit (approximately 10%) is sent to the acid neutralization plant.

10. Cylinder Wash

Cylinders are returned to Allied from the enrichment facilities. These cylinders contain residual UF_6 and the daughters of uranium that have "grown in" while the cylinders containing UF_6 were in storage. The daughters in general are found plated out on the cylinder walls.

After any residual UF_6 is removed from the cylinder, the cylinder is washed, using a solution of Na_2CO_3 to remove any impurities from the walls and to solubilize the uranium (Fig. II-11). The wash solution is filtered to remove the unleached solids, and the pregnant solution is pumped to join the pregnant solution in the uranium treatment section (Fig. II-10).

The solid residue from the filters contains daughter products of uranium, principally ^{234}Th and ^{234}Pa , and is stored on-site in drums until disposal in a licensed waste disposal facility (EIA 1977).

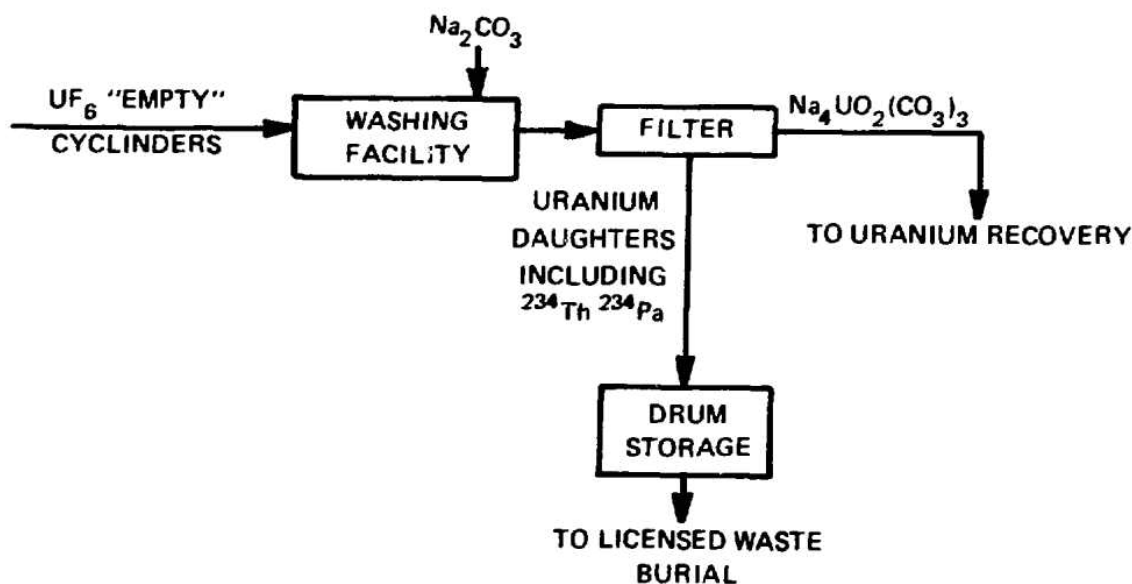


Fig. II-11. Cylinder wash.

11. Sludge Dryer

As previously described, the process generates several sludges that contain uranium. Before being sent for uranium recovery, these sludges are dried in a calciner (Fig. II-12). Off-gases containing SO_2 , HF, and particulates from the calcining operation pass through a baghouse and a water spray tower before discharge by means of the 4-2 stack (EIA 1977).

The spent scrubber water, which contains uranium, fluoride compounds, and some sulfur compounds, is sent to the uranium recovery ponds.

The calcined sludges are drummed and stored until they can be processed in the uranium recovery section.

12. Storage and Handling

Large quantities (Table II-1) of chemicals are shipped to the Metropolis Works. These chemicals must be unloaded and stored until use. All storage tanks are vented through a scrubbing system.* Figure II-13 indicates off-gas treatment for the lime-storage facility.

13. Liquid Treatment

EPA, in their Field Inspection Notes, describe the liquid treatment as follows (Hosey and Hill 1980).

*This information provided by A. J. Cipolla, Allied, June 1981.

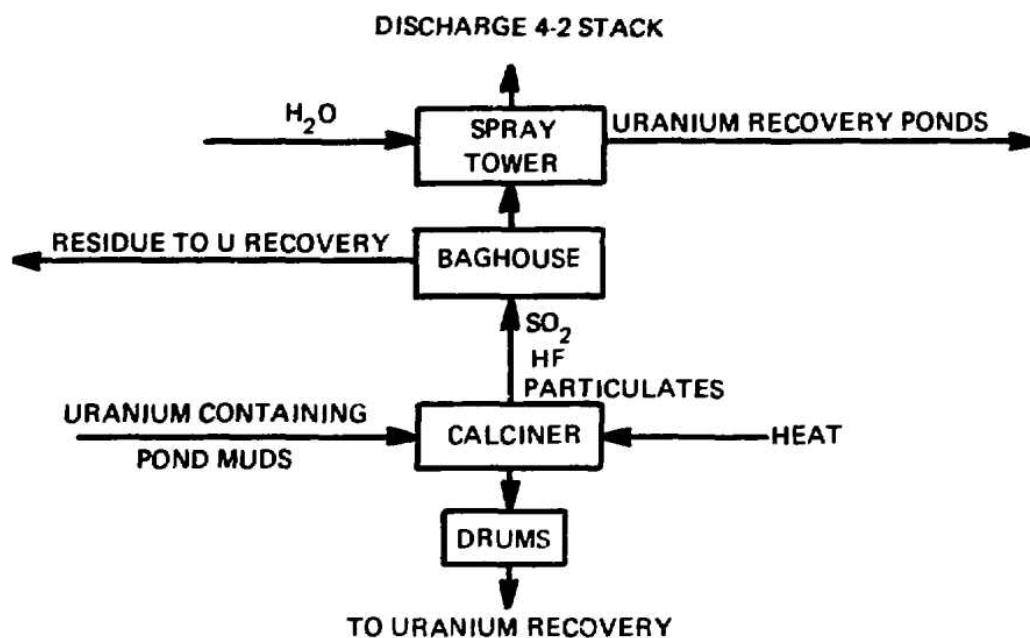


Fig. II-12. Sludge dryer.

TABLE II-1

INBOUND SHIPMENTS OF CHEMICALS TO METROPOLIS WORKS

Commodity	Physical Description	Hazardous Nature as Defined by DOT (if applicable)	Packaging Requirements	Transportation Mode	Average Frequency of Shipments
Hydrogen fluoride	Liquid	Corrosive	DOT special tank cars	Rail tank cars	11 C/L ^a per month
Potassium bifluoride	Solid, dry		Drums	Truck	170 drums per quarter
Sulfuric acid	Liquid	Corrosive	DOT special tank cars	Tank cars and trucks	1 C/L per month
Lime (hydrated)	Solid, dry		Bulk	Tank trucks	276 T/L ^b per year
Potassium hydroxide	Liquid	Corrosive	DOT special tank cars	Rail tank cars	9 C/L per month
Anhydrous ammonia	Liquid compressed gas	Nonflammable compressed gas	DOT special tank cars	Rail tank cars	4 C/L per month

^aTypical carload (C/L) is 80 000 to 120 000 lb net.

^bTypical truckload (T/L) is 30 000 to 40 000 lb net.

Source: EIA, 1977.

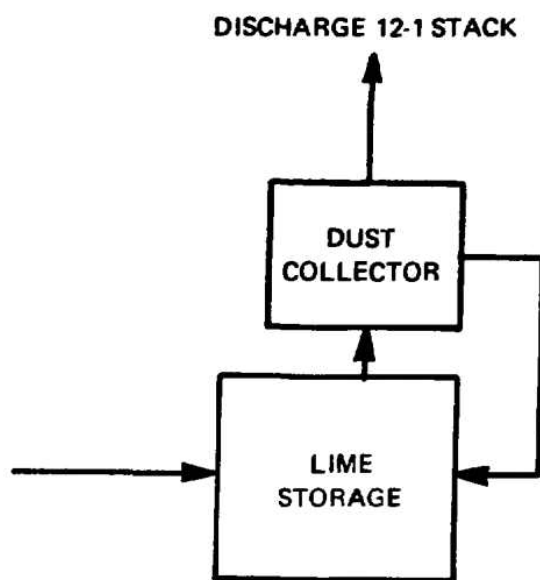


Fig. II-13. Lime plant.

"1. Acid Neutralization

Fluoride bearing wastewaters and spent alkaline wastewaters are processed through acid neutralization utilizing three agitator tanks in series. The first agitator tank is used to premix the two wastewater streams. The premixed liquid then flows by gravity to the second neutralizer or agitator tank and then to the third tank for final adjustment. Lime slurry is added as required to each of the tanks from a lime slurry circulating system. The lime slurry is mixed with water to give approximately 10% slurry and is circulated continuously throughout the system to prevent settling. Overflow from the third neutralizer tank flows to one of the two reslurry tanks, which are discharged to the settling ponds.

"Two settling ponds in series are utilized to provide for maximum solid separation and storage for the settled solids. The clarified treated process wastewater from the second settling pond is pumped to an agitator tank for pH adjustment. Sulfuric acid is added to control the pH of the treated process wastewater between 4 and 10 pH. The discharge from the pH adjustment tank is then discharged into the effluent stream. Flow measurement at the pH adjustment tank is provided by a V-notch weir. During the time of inspection the pH control system was under revision in order to provide two stage automatically controlled pH adjustment capability.

"2. Potassium Hydroxide Regeneration

Potassium hydroxide regeneration is accomplished by addition of hydrated lime to the spent potassium hydroxide scrubbing solution. The overflow from the regeneration after addition of hydrated lime is pumped to a vacuum filter and then to a 50 foot diameter clarifier for initial solid separation. The overflow from the clarifier is pumped through polishing filters for further solids removal and then to potassium hydroxide storage. From the storage the regenerated potassium hydroxide is pumped to various areas for reuse.

"The clarifier underflow is pumped to one of two rotary vacuum filters for removal of solids. Filter cake from the vacuum filters is discharged to the ore sludge slurry tank and pumped to the settling ponds. Filtrate from the vacuum filter is returned to the clarifier."

14. Summary

Waste effluents from the Allied facility include air, water, and solid waste. These discharges are summarized in Table II-2. Monitoring data are given later.

C. Available Data for Routine Waste/Effluent Releases, Storage, and Disposal

1. Air

Table II-3, taken from the Environmental Impact Appraisal, indicates airborne effluents for the Allied Chemical facility when processing 14 000 tons (12 700 metric tons) uranium per year. Table II-4 summarizes the data and indicates releases in kilograms per metric ton uranium processed.

The Nuclear Regulatory Commission (NRC), in the 1977 Environmental Impact Appraisal, modeled ambient levels of HF using the release data given in Table II-3. It was concluded that some vegetation damage might occur near the plant boundary for vegetation most susceptible to damage caused by HF. Sampling data for fluorides in vegetation during 1971-76 are given in Table II-5. More recent data do not appear to be publically available.

Table II-6 indicates the semiannual radiological air effluent releases for radionuclides as reported to NRC. This table also converts the releases to microcuries per metric ton uranium, assuming the facility was running at 12 700 metric ton/yr of uranium throughput.

TABLE II-2
SUMMARY OF PRIMARY DISCHARGES

Section	Air	Liquid	Solids
Storage	Radon	Rain runoff to U recovery ponds	None
Sampling	Concentrate dust, radon	Washdown containing concentrate to U recovery ponds	None
Pretreatment	NH ₃	(NH ₄) ₂ SO ₄ , Na ₂ SO ₄ , K ₂ SO ₄ , small per cent of concentrate to uranium recovery ponds	None
(NH ₄) ₂ SO ₄	NH ₃	None	None
Feed preparation	All radon in equilibrium, concentrate dust, NH ₃ , and SO ₂	None	None
Calciner heater	NO _x , CO ₂	None	None
Dryer heater	NO _x , CO ₂	None	None
Reduction	H ₂ , NO _x , H ₂ S, AsH ₃ , SeH ₂ , uranium compounds, N ₂ , and SO ₂	None	Condensed sulfur to storage
Hydrofluorination	HF, H ₂ S, N ₂ uranium compounds, Si, B, Mo, and V compounds	Water scrubber HF, F, U, Si, and B compounds to acid treatment; KOH liquids to KOH regeneration	None
Fluorination	F ₂ , HF, V, and Mo compounds; uranium compounds	F, V, Mo, Si, C, and S compounds sent to KOH regeneration; K ₂ U ₂ O ₇ sent to pretreatment	Distillation residues to storage (Mo, V, Si, B, U, F) Fluorination ash to uranium recovery
Fluorine production	HF, F ₂ , H ₂	Scrubber liquid containing F compounds to acid treatment	Cell sludge to acid sludge ponds
Uranium recovery	²²⁶ Ra, ²³⁰ Th, U, Si, F compounds, and ingrown radon	²²⁶ Ra, ²³⁰ Th, U, Si, Na, and F compounds sent to acid treatment	Radioactive solid wastes to licensed burial
Cylinder wash	None	None	To licensed burial
Sludge calciner	SO ₂ , HF, and particulates	U, F, and S compounds to U recovery ponds (from scrubber)	None
Chemical storage	Chemicals		

TABLE II-3

AIR EFFLUENT SOURCES, TYPES, AND QUANTITIES

Stack Number	Identification	Height (ft)	Actual Air Flow (ACFM)	Emissions (lb/year) ^a and Stack Concentration ^b									
				HF		Uranium ^c		SO ₂		NH ₃		H ₂ S	
				(lb/yr)	(ppm)	(lb/yr)	(μCi/mf)	(lb/yr)	(ppm)	(lb/yr)	(ppm)	(lb/yr)	(ppm)
1-1	Wet oxide dust collector	98	5040			115.6	4.7 × 10 ⁻¹⁰	8800	40	6570	75		
1-2	Dry oxide dust collector	105	2650			30.7	2.5 × 10 ⁻¹⁰						
1-3	Drum dump dust collector	40	4320			55.4	3.5 × 10 ⁻¹⁰						
1-4	Oxide vacuum cleaner	98	428			10.0	4.8 × 10 ⁻¹⁰						
1-7	UF ₄ vacuum cleaner	12	1078			29.7	6.6 × 10 ⁻¹⁰						
1-8	Ore dryer combustion gas	100	2625			Nil							
1-9	Ore calciner combustion gas	100	2625			Nil							
1-10	UF ₄ dust collector	98	2889	876	35	35.5	7.9 × 10 ⁻¹⁰						
1-11	Drum cleaner dust collector	40	5880			18.0	1.3 × 10 ⁻¹⁰						
1-12	Ash dust collector and vacuum cleaner	86	2561			22.0	1.8 × 10 ⁻¹⁰						
1-13	"A" coke box	105	193	40	12	80.5	1.3 × 10 ⁻⁸						
1-14	"B" coke box	105	193	40	12	55.0	1.1 × 10 ⁻⁸						
1-15	"A" reductor spill discharge	75	987			1.0	2.8 × 10 ⁻¹¹						
1-16	"B" reductor spill discharge	75	987			13.2	3.7 × 10 ⁻¹⁰						
1-17	"A" top hydrofluorinator spill damper	45	6630			9.8	4.0 × 10 ⁻¹¹						
1-18	"A" bottom hydrofluorinator spill damper	12	6630			0.7	2.8 × 10 ⁻¹²						
1-19	"B" top hydrofluorinator spill damper	38	987			57.7	1.6 × 10 ⁻⁹						
1-20	"B" bottom hydrofluorinator spill damper	15	987			1.8	5.0 × 10 ⁻¹¹						
1-21	"A" fluorinator spill damper	30	987			6.2	1.7 × 10 ⁻¹⁰						
1-22	"B" fluorinator spill damper	30	987			3.0	8.4 × 10 ⁻¹¹						
1-23	"A" HF scrubber	20	30			Nil						6.6	5.9
1-24	"B" HF scrubber	20	30			Nil						6.6	5.9
1-25	Dravo heater exhaust	94	578			Nil							
1-26	Hartzell exhaust	60	14 145			31.8	4.7 × 10 ⁻¹¹						

^aEmissions based on rated capacity of facility (14 000 N.T. U, 1200 N.T. SF₆, 30 000 lb/week liquid F₂, 2500 lb/week SbF₃, and 10 000 lb/week IF₃).

^bStack concentrations reported in ppm by volume.

^cActual measured emissions for 1975 operating year.

^dF₂ dumped during abnormal operation only.

^eCa(OH)₂ recorded as 576 lb/year and 3.7 ppm in the effluent treatment plant lime silo dust collector.

Source: EIA, 1977.

TABLE II-3 (cont)

Stack Number	Identification	Height (ft)	Actual Air Flow (ACFM)	Emissions (lb/year) ^a and Stack Concentration ^b									
				HF		Uranium ^c		SO ₂		NH ₃		H ₂ S	
				(lb/yr)	(ppm)	(lb/yr)	(μCi/mf)	(lb/yr)	(ppm)	(lb/yr)	(ppm)	(lb/yr)	(ppm)
1-27	Exhaust fan - 1st floor	15	23 000			0.3	2.7×10^{-13}						
1-28	Exhaust fan - 1st floor	15	23 000			6.7	6.0×10^{-12}						
1-29	Exhaust fan - 2nd floor	30	23 000			25.5	2.3×10^{-11}						
1-30	Exhaust fan - 3rd floor	45	23 000			16.1	1.4×10^{-11}						
1-31	Exhaust fan - 3rd floor	45	23 000			22.1	2.0×10^{-11}						
1-32	Exhaust fan - 3rd floor	45	23 000			22.9	2.0×10^{-11}						
1-33	Exhaust fan - 3rd floor	45	23 000			24.3	2.2×10^{-11}						
1-34	Exhaust fan - 4th floor	60	23 000			35.6	3.1×10^{-11}						
1-35	Exhaust fan - 4th floor	60	23 000			52.0	4.7×10^{-11}						
1-36	Exhaust fan - 4th floor	60	23 000			32.7	2.9×10^{-11}						
1-37	Exhaust fan - 5th floor	75	23 000			28.2	2.6×10^{-11}						
1-38	Exhaust fan - 5th floor	75	23 000			49.6	4.4×10^{-11}						
1-39	Exhaust fan - 5th floor	75	23 000			122.6	1.1×10^{-10}						
1-40	#1 overhead exhaust fan	90	25 000			6.2	5.1×10^{-12}						
1-41	#2 overhead exhaust fan	90	25 000			7.1	5.8×10^{-12}						
1-42	#3 overhead exhaust fan	90	25 000			4.8	4.0×10^{-12}						
1-43	#4 overhead exhaust fan	90	25 000			Nil							
1-44	#5 overhead exhaust fan	90	25 000			Nil							
1-45	NH ₃ dissociator vent	60	12 580			17.7	2.9×10^{-11}						
1-46	UF ₆ back-up dust collector	not installed to date											
1-47	"C" fluorinator spill damper	30	987			0.9	1.9×10^{-11}						
1-48	H ₂ S incinerator	155	6500			0.1	3.2×10^{-13}	4.4×10^3	6855				
2-1	Na removal, 4th settler and reslurry	36	110							1836	1438		
2-2	Na removal, 3rd reslurry	36	100							1836	1581		
2-3	Na removal, 2nd reslurry	36	100							1836	1581		
2-4	Na removal, sewerage tanks	38	115							1836	1377		
2-5	Na removal, 2nd & 3rd settlers	38	115							1836	1377		
2-6	Na removal, 1st settler & reslurry	36	110							3400	2664		
2-7	Na removal, NH ₃ , SO ₂ reactor	33	5							76	1314		
3-1	U-recovery, milled ash storage	28	100										
3-2	U-recovery, dust collector	18	3296										
3-3	U-recovery, 1st leach tank	12	120										
3-4	U-recovery, 2nd leach tank	12	120										
3-5	U-recovery, precipitator	12	120										
4-1	Pond muds calciner, combustion gas	35	856										
4-2	Pond muds calciner, scrubber vent	29	3005	3240	193	0.9	6.2×10^{-12}	180	3.4				

TABLE II-3 (cont)

Stack Number	Identification	Height (ft)	Actual Air Flow (ACFM)	Emissions (lb/year) ^a and Stack Concentration ^b									
				HF		Uranium ^c		SO ₂		NH ₃		H ₂ S	
				(lb/yr)	(ppm)	(lb/yr)	(μCi/mf)	(lb/yr)	(ppm)	(lb/yr)	(ppm)	(lb/yr)	(ppm)
5-1	5KA fluorine plant, KOH scrubber	35	5	94	3.2 × 10 ⁴								
5-2	5KA fluorine plant, H ₂ scrubber	30	90	2628	1839								
6-1	15KA fluorine plant, KOH scrubber	35	5	94	3.2 × 10 ⁴								
6-2	15KA fluorine plant, H ₂ scrubber	40	80	4179	2126								
7-1	Powerhouse, #1 boiler	50	7680					425	0.64				
7-2	Powerhouse, #2 boiler	50	7680					425	0.64				
7-3	Powerhouse, #3 boiler	50	7680					213	0.64				
8-3	SF ₆ plant, IF ₃ scrubber	24	2.3	2.3	426								
8-4	SF ₆ plant, SbF ₅ scrubber	14	1	103	1.9 × 10 ³								
9-2	Laboratory hood scrubber	18	18 900										
11-1	15KA fluorine plant additional KOH scrubber	35	5	94	3.2 × 10 ⁴								
11-2	15KA fluorine plant additional H ₂ scrubber	40	120	394	134								
11-3	15KA fluorine plant additional melt tank scrubber	40	2	71	4.3 × 10 ⁴								
12-1	Effluent treatment plant lime silo dust collector ^d	50	2100										

TABLE II-4
AIR RELEASES ALLIED CHEMICAL
UF₆ FACILITY^{a,b,c}
(14 000 T/YR)

Type	kg/yr	kg/MTU ^d
Uranium	482.6	0.04
SO ₂	204 139.0	16.07
HF	5377.6	0.42
NH ₃	8721.0	0.69
H ₂ S	5.99	0.0005

^aDoes not correct for emissions caused by manufacture of liquid F₂, SbF₅, SF₆, IF₅ (SF₆ plant releases about 48 kg/yr of HF).

^bDoes not include boiler combustion products.

^cDoes not include storage losses.

^dMTU - metric tons uranium.

Table II-7 indicates locations of air sampling stations, and Table II-8 shows average radiological concentrations at these sampling stations (OML).

Using the radiological data given in Table II-8, the solubility classification data obtained by Kalkwarf (see reference noted Kalkwarf 1980) and a suitable model, NRC staff calculated that if an infant lived at the nearest residence, the lung dose caused by the UF₆ facility would be approximately 42.5 mR/yr. (For more information on this calculation, the reader is referred to OML).

Allied personnel recently informed the NRC staff that monitoring data obtained by Allied, which includes ²³⁰Th and U_{nat} concentrations, size distributions, and solubility, indicate a dose of approximately 10 mR/yr to an adult living at the nearest residence.* The critical parameters in determining the dose appear to be concentration, size distribution, and solubilities of airborne U_{nat}, ²³⁰Th, and ²²⁶Ra. The ²³⁰Th in particular appears to be very important in the possible exposure.

2. Water

There is only one discharge point for the Allied facility. Figure II-14 indicates the various sources of this liquid discharge. Data on water quality as reported in the Environmental Impact Appraisal are given in Table II-9,

whereas Table II-10 indicates recent water quality reported by Allied to EPA as required by the NPDES permit. Table II-11 indicates data for a sample taken by the EPA staff during an inspection in November 1980.

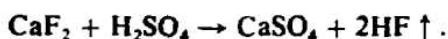
Table II-12 indicates early data for the radiological parameters, whereas Tables II-13 and II-14 give more recent data.

During 1975-1976, the concentration of uranium in the discharge averaged between 0.7 to 0.9 ppm. During the period January 1975 to July 1976, soluble ²²⁶Ra had concentrations ranging from a minimum of less than 4.2×10^{-10} $\mu\text{Ci}/\text{ml}$ to a maximum of 9.1×10^{-9} $\mu\text{Ci}/\text{ml}$ (Table II-13). This latter value represents about 30% of the 10 CFR 20 limit, and the NRC staff recommended that improved methods of control be investigated (SER).

Combustion Engineering, under contract to Allied, has collected mud samples of the river bottom and three area lakes for uranium and fluoride content. The author was unable to obtain these data.

3. Sludges

At the plant site, there are now approximately 84 000 tons (76 188 metric tons) of spent limestone calcium fluoride sludge produced from treatment of liquids containing minimum amounts of uranium. Approximately 33 000 tons (29 931 metric tons) of the 84 000 tons are reacted calcium fluoride. Allied plans in the next several years to begin a sludge regeneration program. The sludge presently on-site and sludge being generated will be reacted with hydrofluoric acid to convert the remaining limestone into CaF₂ (the reacted sludge will contain approximately 90% by dry weight of CaF₂). After drying, the material will be sent off-site to another Allied facility where the CaF₂ will be reacted with sulfuric acid to evolve HF for recovery in condensers.



4. Solid, Nonsludge Wastes

Approximately four hundred 55-gallon drums of uranium and uranium daughter contaminated trash, consisting of blotting paper, floor sweeping compounds, cleaning rags, etc., are sent annually to a commercial burial site (SER).

The solid residues filtered from the leachate at the uranium recovery facility consist primarily of fluoride compounds that contain U_{nat}, ²³⁰Th, ²²⁶Ra, and other minor constituents, such as molybdenum and vanadium. These residues are dried and placed in 55-gallon drums

*This information provided by W. T. Crowe, NRC, August 1981.

TABLE II-5

RESULTS OF ALLIED SAMPLING OF VEGETATION FOR FLUORIDE CONTENT
FROM 1971-1976^a

Fluoride Content of Vegetation (ppm dry weight)											
Station	1971		1972		1973		1974		1975		1976
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring ^b
1	0.9	120.0	<0.25	2.5	18.5	18.0	4.6	<5	6.8	14.4	2.8
2	0.6	528.0	<0.25	3.2	7.0	8.0	4.5	6	<5	12.8	2.5
3	0.5	41.0	26.5	2.8	5.8	32.0	4.6	7	7.5	424.8 ^c	<2
4	0.6	6.0	<0.25	2.0	0.3	<2.5	4.6	<5	6.0	7.6	<2
5	0.9	1080.0	<0.25	5.0	4.0	<2.5	4.1	6	32.0	7.5	<2
6	0.9	53.0	<0.25	3.2	0.9	<2.5	3.2	6	7.0	20.0	1.9
7	0.6	75.0	<0.25	6.5	3.2	<2.5	2.0	7	<5	16.0	2.8
13	0.9	420.0	<0.25	5.5	15.0	<2.5	4.5	10	20.4	19.5	2.8

^aStation 13 was located onsite at an agricultural field.^bThe fall values were not available.^cBelieved to be an error.

Source: SER and responses to Nuclear Regulatory Commission questions.

TABLE II-6

RADIOLOGICAL EFFLUENT RELEASES TO THE AIR

Period	Discharge					
	U _{nat}	U _{nat} μ Ci ^a	²³⁰ Th	²³⁰ Th μ Ci ^a	²²⁶ Ra	²²⁶ Ra μ Ci ^a
	(μ Ci)	(MTU) ^b	(μ Ci)	(MTU)	(μ Ci)	(MTU)
July-Dec 1976	180 000	28.3	760	0.12	46	0.01
Jan-June 1977	130 000	20.5	980	0.15	44	0.01
July-Dec 1977	160 000	25.2	1600	0.25	29	0.004
Jan-June 1978	170 000	26.8	1000	0.16	45	0.01
July-Dec 1978	120 000	18.9	NA	—	NA	—

^aAssuming 6350 metric tons uranium per six month period.^bMTU - metric tons uranium throughput.

Source: Reports to NRC.

TABLE II-7
LOCATIONS OF ENVIRONMENTAL AIR SAMPLING STATIONS

Air Sampler Number	Location
6	5300 ft NNE (Metropolis Airport)
8	1035 ft NE of UF ₆ Building
9	775 ft NNW of UF ₆ Building
10	720 ft SW of UF ₆ Building
11	1240 ft N of UF ₆ Building
12	590 ft SSE of UF ₆ Building
13	755 ft NE of UF ₆ Building

Source: Order to Modify License, Amendment No. 4.

TABLE II-8
SUMMARY OF ENVIRONMENTAL AIR MONITORING RESULTS IN 1979

Sample Point	1979 Data Average Concentration (μCi/m ³)				
	²³⁴ U	²³⁵ U	²³⁸ U	²²⁶ Ra	²³⁰ Th
6	2.64×10^{-15}	1.22×10^{-16}	2.64×10^{-15}	4.57×10^{-17}	2.79×10^{-16}
8	8.99×10^{-15}	4.13×10^{-16}	8.99×10^{-15}	6.08×10^{-17}	3.08×10^{-15}
9	1.42×10^{-14}	6.51×10^{-16}	1.42×10^{-14}	a	a
10	1.72×10^{-14}	7.91×10^{-16}	1.72×10^{-14}	a	a
11	1.42×10^{-14}	6.51×10^{-16}	1.42×10^{-14}	4.20×10^{-17}	1.70×10^{-15}
12	1.36×10^{-14}	6.27×10^{-16}	1.36×10^{-14}	a	a
13	1.53×10^{-14}	7.05×10^{-16}	1.53×10^{-14}	a	a

*The licensee analyzed only the air samples at stations No. 6, 8, and 11 for ²²⁶Ra and ²³⁰Th. Analysis of air samples showed the ratio of ²³⁰Th to natural uranium to be much higher than the yellow-cake feed average over 33 mills (²³⁰Th/U-natural = 0.0052).

Source: Order to Modify License, Amendment No. 4.

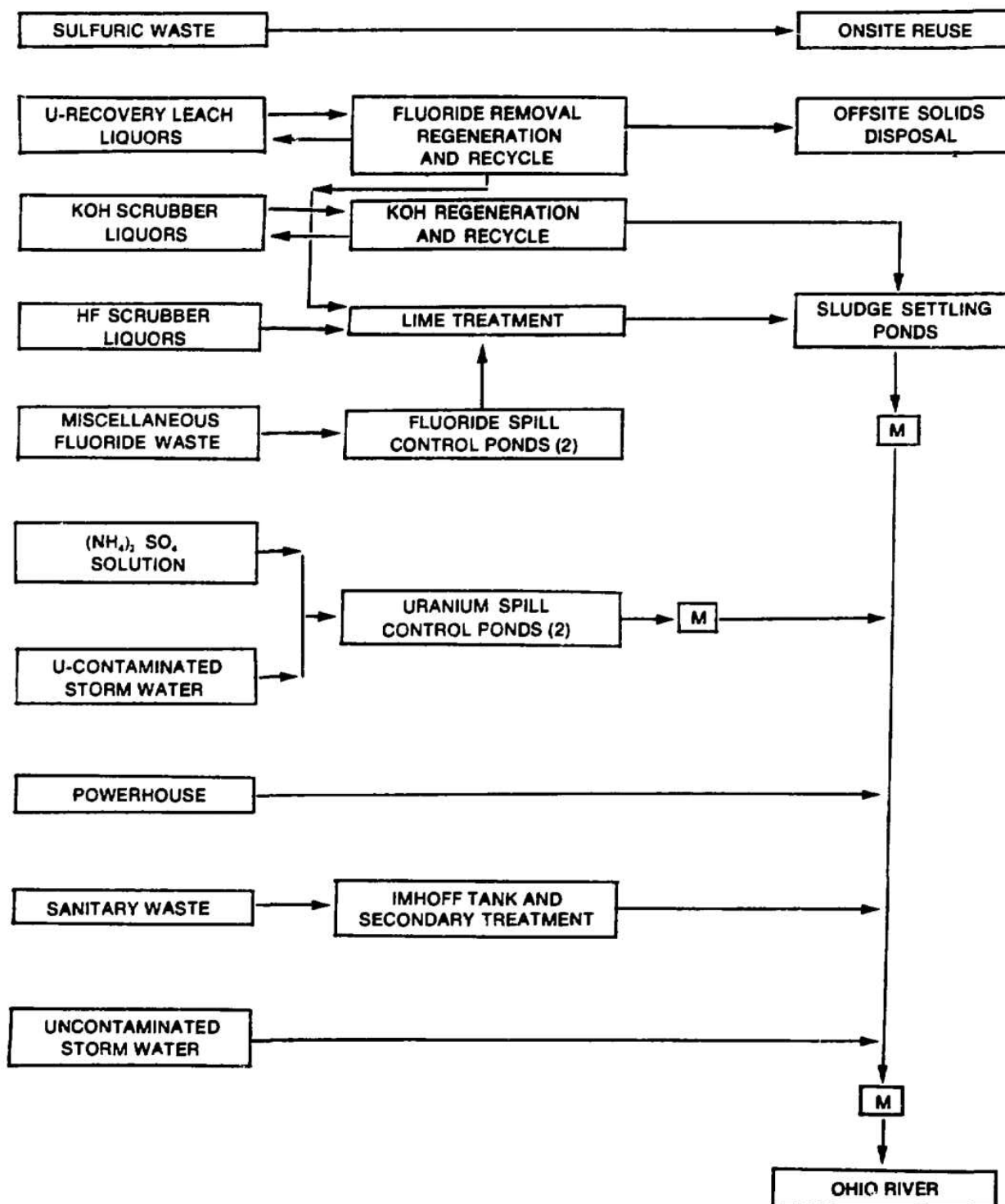


Fig. II-14. Current wastewater disposition. M = monitoring station.

Source: EIA 1977.

TABLE II-9

LIQUID EFFLUENT CONTAMINANT LEVELS AT COMBINED (SANITARY AND PROCESS) OUTFALL

Sampling Frequency Weekly or Greater

Parameter	Average ppm 12 Months Ending April 1, 1976	Average ppm April 1, 1976 to April 1, 1977
Arsenic	0.15	0.03
Chloride	26.3	28.9
Chromium (Cr ³⁺)	0.05	0.03
Chromium (Cr ⁶⁺)	0.003	0.003
Fluoride	149	8.3
Iron	0.51	0.21
Molybdenum	0.12	0.08
Nickel	0.07	0.02
pH (average)	7.1	7.6
Phosphate	1.4	1.3
Silver	0.07	0.04
Solids (total dissolved) ^a	904	636
Solids suspended	74	3.4
Sulfate ^a	84	234
Vanadium	0.15	0.08
Average flow (Mgd)	3.46 × 10 ⁶	3.21 × 10 ⁶

^aThis varies directly with the sulfate content of incoming ore.

Source: EIA 1977.

for shipment to a commercial burial site. It is reported that 1500 tons (1361 metric tons) of this material, containing a calculated maximum of 46.9 Ci of total activity, is produced annually (EIA 1977). Table II-15 indicates data on the individual radionuclides. (Recent data from Allied indicate 188 pCi ²²⁶Ra and 3600 pCi ²³⁰Th per gram of uranium in the current feed concentrate, or slightly more than ²³⁰Th than the 1976 concentrate.)^{*} It appears that because most of the activity caused by these radionuclides is alpha decay, the gross alpha activity of this drummed material is approximately 34.5 nCi/g.

Contaminated pieces of no longer usable process equipment are decontaminated so far as is feasible and then delivered by rail car to a dealer of radioactive contaminated metal scrap. Noncontaminated scrap is sold to various scrap dealers (EIA 1977).

As far as could be determined, condensed sulfur is stored at the site, as well as residues from the UOF₃ condenser and high boiler column.

^{*}Letter from A. J. Cipolla to Betty Perkins, June 29, 1981.

D. Inadvertent Releases Involving Wastes and Effluents

1. Operational

From time to time, there will be small vent releases of toxic materials caused by over-pressurizing, seal failure, loss of power, plant cleanup and repair operations, process problems, etc. Discharges into the plant buildings may be released to the ambient environment because there are no off-gas cleanup systems operating on the building exhaust vents.

These types of releases would be expected to occur fairly frequently; however, there are no data publically available as to frequency, rate of release, and types of release.

2. Releases from Pond Operations

The plant is located less than 1 mile from the Ohio River. A breach in the dikes of the fluorine treatment ponds could result in some movement of CaF₂ sludge and some loss of fluorine-containing liquids. A breach in the uranium settling ponds could discharge uranium-containing sludge, whereas a breach in the fluoride spill control ponds could discharge fluoride compounds and small amounts of uranium. A breach could be caused by a break in the fill line causing erosion of the embankment, etc. The ponds are lined and underlain by gravel drain-leak-detection systems, so it would not appear that breach by tunneling caused by liquid-soil interactions would occur.

3. Releases Caused by Rupture of Ducts and Piping Carrying Waste Streams

Other types of accidents involving wastes would be for a liquid transfer line to break or for a line carrying gaseous waste discharge to rupture before entering the cleanup system. The consequences of such breaks would depend on the type of line, size of rupture, etc.

4. Failure of Effluent and Waste Treatment Equipment

Inadvertent releases could also occur if any dust collection equipment developed failures that resulted in channeling the gas flow around the collector. Inadvertent releases of fluoride compounds might occur if any of the various scrubbing systems became clogged, the liquid flow was reduced, contact time was reduced, there was mist eliminator failure, etc.

TABLE II-10

ALLIED MONITORING (NPDES) OUTFALL WATER QUALITY

Date	Flow (MGD)	Flow (m ³ /day)	TDS (mg/l)	Maximum TSS (mg/l)	Maximum F (mg/l)	pH ^{min}	pH ^{max}
Dec 1980	4.717	17 854	1071	1.3	7.6	6	7.5
Nov 1980	4.564	17 275	669	4.6	12.8	6.1	8.3
Oct 1980	4.741	17 944	1190	2.1	8.2	6.0	9.0
Sept 1980	4.481	16 983	785	1.9	7.4	3.9	8.3
Aug 1980	4.599	17 407	752	7.0	5.6	6.9	8.5
July 1980	4.468	16 911	824	1.8	9.2	6.5	8.4
June 1980	4.844	18 334	859	1.6	14.0	7.1	8.6
May 1980	4.203	15 908	966	2.2	6.2	6.4	9.3
April 1980	4.188	15 852	946	2.8	5.8	6.1	9.2
March 1980	4.325	16 370	904	2.0	6.0	5.9	8.8
Feb 1980	4.043	15 303	948	2.0	7.0	6.1	8.8
Jan 1980	4.155	15 727	836	6.0	7.0	6.0	8.7
Dec 1979	4.210	15 935	968	1.0	6.0	6.2	8.9
Nov 1979	4.106	15 541	1078	5.0	16.0	6.5	9.0
Oct 1979	3.826	14 481	849	3.0	8.0	6.6	8.7
Sept 1979	4.055	15 348	1244	3.0	10.0	6.0	8.7
Aug 1979	4.015	15 197	973	3.0	19.0	6.3	9.2
July 1979	3.740	14 155	1176	2.0	11.0	6.3	8.8
June 1979	3.986	15 087	754	64.0	11.0	6.1	8.0
May 1979	4.025	15 234	922	9.0	8.0	6.4	8.7
April 1979	4.239	16 044	838	60.0	8.0	3.6	8.7
March 1979	4.380	16 578	931	12.0	9.0	6.2	8.8
Feb 1979	4.796	18 152	1382	4.0	14.0	6.5	8.2
Jan 1979	3.857	14 598	1007	4.0	5.0	6.7	8.4

Source: NPDES reports by Allied Chemical to EPA.

TABLE II-11

WATER QUALITY OF EPA SAMPLE
AT OUTFALL

Item	Concentration mg/l
Arsenic	0.002
Barium	0.04
Boron	0.04
Chromium (tot.)	0.02
Copper	0.02
Iron (tot.)	0.06
Manganese	0.01
Selenium	0.003
Zinc	0.02
Fluoride	6.5
Phenols	0.0
TSS	2.0
pH	6.8

Source: EPA compliance inspection.

TABLE II-12

RADIOACTIVITY IN FACILITY LIQUID EFFLUENT

	1962	1969	1971	1973
Average alpha activity (pCi/ml)	0.51	0.031	0.188	0.217
Maximum alpha activity pCi/ml	0.58	0.065	0.560	0.500
Average beta activity (pCi/ml)	NA	0.247	0.377	0.516
Maximum beta activity pCi/ml	NA	0.402	0.770	1.11
Average uranium (ppm)	3.1	1.0	0.7	0.7

Source: EIA 1977.

TABLE II-13

**ISOTOPIC ANALYSIS OF METROPOLIS WORKS
EFFLUENT WATER (002 OUTFALL) IN
MICROCURIES PER MILLILITER**

	²³⁵ U		U Natural		²²⁶ Ra		²³⁴ Th		²³² Th	
	Soluble	Insoluble	Calculated ^a	Wet ^b	Soluble	Insoluble	Soluble	Insoluble	Soluble	Insoluble
1975										
January	6.0×10^{-9}	1.0×10^{-8}	1.1	1.0	2.1×10^{-8}	5.2×10^{-9}	1.0×10^{-9}	1.0×10^{-9}	1.7×10^{-8}	1.0×10^{-9}
February	3.0×10^{-10}	7.4×10^{-10}	0.1	0.8	2.6×10^{-9}	6.7×10^{-8}	1.0×10^{-9}	5.2×10^{-7}	1.8×10^{-10}	8.4×10^{-8}
March				1.8	Sample discarded before isotopic analysis					
April	2.9×10^{-8}	9.5×10^{-9}	2.5	1.1	4.0×10^{-9}	7.2×10^{-8}	1.6×10^{-7}	5.8×10^{-7}	1.4×10^{-8}	6.6×10^{-8}
May	1.0×10^{-8}	3.0×10^{-10}	0.7	1.0	7.4×10^{-9}	6.8×10^{-8}	1.0×10^{-9}	8.1×10^{-7}	3.4×10^{-10}	7.4×10^{-8}
June	4.5×10^{-9}	3.3×10^{-9}	0.5	0.5	1.8×10^{-9}	5.3×10^{-8}	6.4×10^{-9}	4.2×10^{-7}	1.8×10^{-10}	4.4×10^{-9}
July	5.8×10^{-9}	1.0×10^{-8}	1.1	0.5	9.1×10^{-9}	1.0×10^{-8}	5.4×10^{-8}	2.2×10^{-7}	1.8×10^{-10}	1.0×10^{-9}
August	4.7×10^{-9}	8.8×10^{-9}	0.9	0.8	4.2×10^{-10}	1.0×10^{-9}	6.2×10^{-8}	2.1×10^{-7}	1.8×10^{-10}	1.0×10^{-9}
September				0.5	Sample discarded before isotopic analysis					
October	8.5×10^{-9}	c	0.3	1.0	4.4×10^{-9}		1.2×10^{-7}		1.8×10^{-10}	
November	6.6×10^{-9}	8.4×10^{-9}	1.0	0.5	8.0×10^{-9}	6.0×10^{-9}	8.3×10^{-8}	1.4×10^{-7}	3.6×10^{-9}	4.8×10^{-9}
December	4.4×10^{-9}	6.3×10^{-9}	0.7	0.2	6.0×10^{-9}	6.7×10^{-9}	6.1×10^{-8}	1.2×10^{-7}	4.3×10^{-9}	3.0×10^{-9}
Average	8.0×10^{-9}	6.4×10^{-9}	0.9	0.8	6.5×10^{-9}	3.2×10^{-8}	5.5×10^{-8}	3.4×10^{-7}	3.2×10^{-9}	2.7×10^{-8}
1976										
January				0.7	Sample discarded before isotopic analysis					
February	2.1×10^{-9}	6.9×10^{-9}	0.6	0.5	3.7×10^{-9}	1.0×10^{-9}	2.9×10^{-8}	1.2×10^{-9}	1.8×10^{-9}	1.0×10^{-9}
March	3.5×10^{-9}	9.3×10^{-9}	0.8	0.6	4.6×10^{-9}	5.8×10^{-9}	2.9×10^{-8}	1.5×10^{-7}	2.5×10^{-9}	1.0×10^{-9}
April	1.1×10^{-8}	3.6×10^{-9}	1.0	0.6	4.2×10^{-10}	5.8×10^{-9}	8.0×10^{-8}	1.0×10^{-7}	2.0×10^{-9}	2.2×10^{-9}
May	1.1×10^{-8}	3.2×10^{-9}	0.9	0.8	2.5×10^{-9}	2.5×10^{-9}	8.6×10^{-8}	1.0×10^{-7}	2.4×10^{-9}	1.7×10^{-9}
June	2.5×10^{-8}	2.2×10^{-9}	1.8	1.7	4.8×10^{-9}	2.9×10^{-9}	1.7×10^{-7}	2.3×10^{-7}	1.8×10^{-10}	1.6×10^{-9}
July	6.8×10^{-9}	2.7×10^{-9}	0.6	0.7	4.8×10^{-10}	3.8×10^{-9}	7.7×10^{-8}	7.0×10^{-8}	1.8×10^{-10}	2.7×10^{-9}
August	1.2×10^{-8}	2.7×10^{-9}	0.9	1.5	5.0×10^{-9}	5.0×10^{-9}	9.9×10^{-8}	1.1×10^{-7}	1.1×10^{-9}	1.7×10^{-9}
Average	1.0×10^{-8}	4.4×10^{-9}	0.9	0.9	3.1×10^{-9}	3.8×10^{-9}	8.3×10^{-8}	1.1×10^{-7}	1.5×10^{-9}	1.7×10^{-9}

^aTotal natural uranium calculated from ²³⁵U concentration.

^bFluorimetric uranium analysis of monthly composite samples.

^cInsoluble portion of sample lost in sample preparation.

Source: EIA 1977.

TABLE II-14

RADIOLOGICAL EFFLUENT RELEASES TO THE WATER

Period	Discharge					
	U_{nat} μCi	U_{nat} μCi^a MTU	^{230}Th μCi	^{230}Th μCi^a MTU	^{226}Ra μCi	^{226}Ra μCi^a MTU
July-Dec 1976	1 240 000	195.3	5200	0.82	22 000	3.46
Jan-June 1977	950 000	149.6	3200	0.50	11 000	1.73
July-Dec 1977	190 000	187.4	3000	0.47	11 000	1.73
Jan-June 1978	950 000	149.6	2300	0.36	26 000	4.09
July-Dec 1978	960 000	151.2	NA	—	NA	—

^aAssuming 6350 metric tons uranium per 6-month period.

Source: Submittals to NRC.

TABLE II-15

ISOTOPIC CONTENT OF URANIUM RECOVERY FACILITY SOLID WASTES

Isotope	Source	Radioactivity (curies)
Uranium (nat)	Unrecoverable	1.9 ^a
^{226}Ra	Long-lived daughters not removed in the milling process	2.1
^{230}Th	Long-lived daughters not removed in the milling process	36.1
Thorium (nat)	Natural thorium not removed in the milling process	6.8
Total		46.9 ^{a,b}

Apparently no data are available for the extent and frequency of treatment equipment failure. Because in many cases Allied has multiple scrubber systems, malfunction of one scrubber should be compensated for to some extent in the other scrubber systems. Allied personnel monitor scrubber pressure drop and temperature at 2-hour intervals, and off-gas scrubber samples are analyzed at 4-hour intervals.

5. Transportation

An accident involving transport of wastes to the contaminated-scrap dealer or the commercial waste burial site could result in release of waste material.

E. Long-Term Releases

One of the major concerns for long-term release will be with the material in the drums sent to the commercial low-level waste burial sites. Most wastes accepted for burial at these sites have fairly short half-lives, and it is usually felt that concern for containment only extends to

^aBased on the 1976 operating year and scaled to 14 000 tons of uranium annual throughput. The licensed material is reasonably uniformly distributed in these dry solids, with an average specific activity of 0.0014 $\mu Ci/g$.

^bShort-lived daughters are not included because of the 1-yr decay time allowed before the material is disposed of. Total activity is calculated by measurement of isotopic content of incoming ore concentrates and subtracting the measured and calculated effluent losses.

Source: EIA 1977.

a few hundreds of years. However, the radioactive wastes from Allied have long half-lives; in addition, long-lived daughters will grow in from the uranium and thorium parents. Thus, adequate containment of these types of wastes at a low-level waste disposal site are of concern.

F. Recommendations

To obtain a better data base for assessment of the Allied UF₆ plant wastes, the following projects should be undertaken.

- (1) Determine the types and quantities of emissions occurring from the reduction stacks and the quantity of uranium in the condensed sulfur from the reduction stack sulfur condenser.
- (2) Study the long-term effects of the liquid discharge on the Ohio River.
- (3) Perform an independent study of the size distribution, solubility, and ambient air concentrations of ²³⁰Th, ²²⁶Ra, and U_{nat} in regions surrounding the plant at locations that may have maximum concentrations as determined by modeling of dispersion of stack emissions.
- (4) Perform an independent study of fluorine concentrations at various times of the year in soils and plants surrounding the facility, particularly at locations that stack emission data and modeling indicate will be areas of maximum fluorine deposition.
- (5) Trace the fates of arsenic, selenium, molybdenum, and vanadium from stack off-gases.
- (6) Determine the ²³⁰Th emissions from the grinding and sizing operations of the uranium recovery circuit to define the need for further off-gas cleanup (that is, 3-2 stack emissions).
- (7) Determine the frequency and types of inadvertent emissions.
- (8) Study sources and extent of fugitive emissions (including emissions from the building vents).
- (9) Provide information on contaminants in decantate from the uranium spill control ponds.
- (10) Perform an independent study of external radiation levels outside the site near the fence and concentrations of uranium and ²³⁰Th in surrounding surface soils.
- (11) Monitor HF emissions from all stacks. (Note: This is also a recommendation of the NRC staff.)
- (12) Monitor independently soluble and insoluble ²²⁶Ra releases in the 002 outfall.
- (13) Determine what trace contaminants are in the CaF₂ sludge that is proposed to be used for manufacture of HF.

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CHAPTER III

KERR-McGEE NUCLEAR CORPORATION— SEQUOYAH

A. Background

In 1970, Kerr-McGee Nuclear began operation of a uranium hexafluoride production facility having a design throughput of 5000 tons (4535 metric tons) of uranium a year. Since then, an expansion program has been completed, doubling throughput to 10 000 tons (9070 metric tons) of uranium a year (Order to Modify License, Amendment 9—OML).

The facility (Fig. III-1) is located in a rural region near Gore, Oklahoma on a 2100-acre site, of which 75 acres is a restricted, fenced area for the conversion facility. The site is bounded on the west by the Illinois and Arkansas Rivers. Detailed data on the geology, hydrology, climate, land use, etc., may be obtained from the Final Environmental Statement (Final Environmental Statement 1975—FES 1975).

Approximately 150 people are employed at the plant.

B. Process Description

1. Introduction

The facility uses the wet solvent extraction-fluorination process to convert uranium concentrates into UF₆. The facility can receive the concentrates either dry in 55-gallon drums or as a wet slurry (FES 1975).

Upon receipt, the concentrate is weighed and sampled. The concentrate is processed by dissolving in nitric acid and removing uranyl nitrate by solvent extraction and stripping. The pure uranyl nitrate is further concentrated and denitrified to produce uranium trioxide (UO₃), after which UO₃ is reduced to UO₂ with cracked ammonia. Next, UO₂ is reacted with anhydrous hydrogen fluoride to produce UF₄. Finally, the UF₄ is converted to UF₆ by reaction with F₂ (FES 1975).

A detailed description of each process step, including the treatment of waste and effluent streams, follows.

2. Receiving and Sampling

Uranium concentrate, received in 55-gallon drums, is weighed and approximately 0.1% of the concentrate removed for sampling by emptying each drum into an elevated hopper and removing representative samples of the concentrate as it moves downward to a collection vessel. The sampled concentrate is either redrummed and stored for future processing or delivered to storage hoppers in the digestion area (FES 1975).

Any dusts produced during sampling and collection are passed through a cyclone and baghouse whose off-gases in turn are routed to the main plant dust collection system. A vacuum cleaner is used to collect any spilled concentrate and clean the drums and sampling system. The vacuum off-gases containing uranium concentrate dusts are sent through a cyclone and baghouse and then are combined with the off-gases from sampling before these gases enter the sampling clean-up system (Fig. III-2). Residues from the two clean-up systems are discharged back to the system (FES 1975; OML).

Rain run-off from the drum storage area drains to a sump where solids are separated and liquids overflow to the outfall.

3. Digestion

Uranium concentrates (including slurries) are fed in batches into three 5000-gallon (18.9 m³) stirred, hot, 40%-nitric-acid digester tanks. The digestors are operated at subatmospheric pressure, with off-gases passed through a small eductor scrubber before being routed to the nitric acid recovery tower (Fig. III-3) (OML; Application for Permit, 1978—AP 1978).

Each batch dissolution takes 2 hours, during which time 552 pounds (250 kg) of NO₂ and 72 pounds (33 kg)

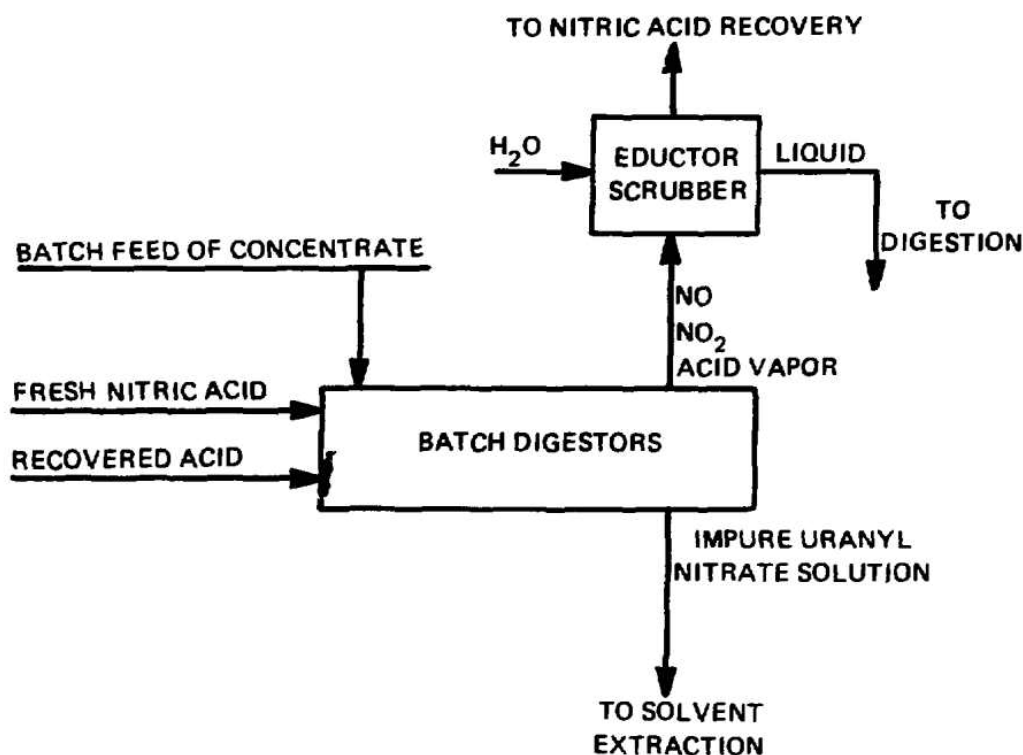


Fig. III-3. Digestion.

of NO are evolved. At the full facility production rate, 20 batches are run per week (AP 1978).

Washdown waters during cleaning of the digestion section are discharged to the digestors.

4. Solvent Extraction and Acid Scrubbing

The impure uranyl nitrate digestion solution is processed by counter-current solvent extraction in pump-decanters using a tributylphosphate-hexane solvent that sorbs the uranyl nitrate (Fig. III-4). The uranium-loaded solvent is scrubbed with slightly acidified water (FES 1975).

Organic vapors emitted through pump seals, etc., are removed from the building by means of the main exhaust system. Hexane off-gases are passed through a condenser (AP 1978).

Discharge from washdown of the facility is routed to the solvent extraction feed tank.

The raffinate (see Fig. III-4) from solvent extraction contains most of the impurities originally present in the uranium concentrate. Typical impurities are ^{226}Ra , ^{230}Th , arsenic, selenium, vanadium, molybdenum, silicon, and sulfur. A small amount of organic solvent and nitrogen compounds is also present. This stream is sent to the raffinate disposal ponds (FES 1975).

5. Stripping and Solvent Purification

The uranyl nitrate is re-extracted into the aqueous phase using extraction pulse columns (Fig. III-5). Any process off-gases are removed in the building process air (FES 1975).

Seal leaks and washdown water are routed to the solvent extraction feed tank.

The barren solvent is purified for recycle by washing with ammonium sulfate and sodium hydroxide. The spent clean-up bleed joins the raffinate stream and is discharged to the raffinate ponds. The off-gases from solvent purification pass through a condenser before discharge through the hexane vent (AP 1978; FES 1975).

6. Scrubbing, Decanting, and Concentration

Any residual organics in the aqueous strip solution are removed in a hexane scrub-decanter. The uranyl nitrate strip solution is initially concentrated in single-effect evaporators and then further concentrated in boil-down tanks to which sulfuric acid or ammonium sulfate [approximately 2.3 lb/hr (1.04 kg/hr) of sulfur] is added to improve product reactivity in subsequent conversion steps (Fig. III-6) (FES 1975; AP 1978).

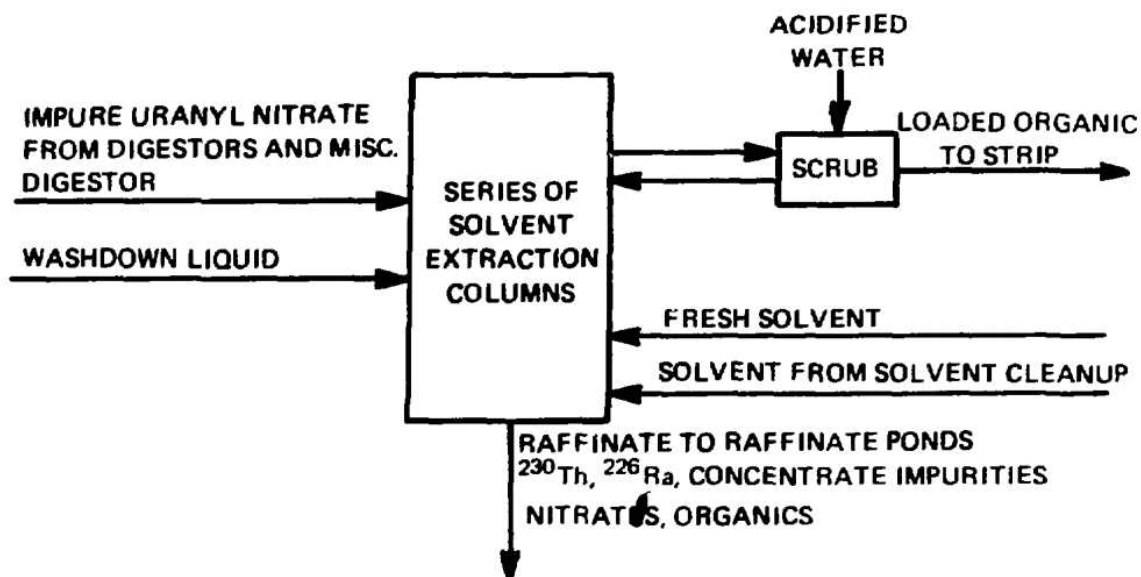


Fig. III-4. Solvent extraction and acid scrubbing.

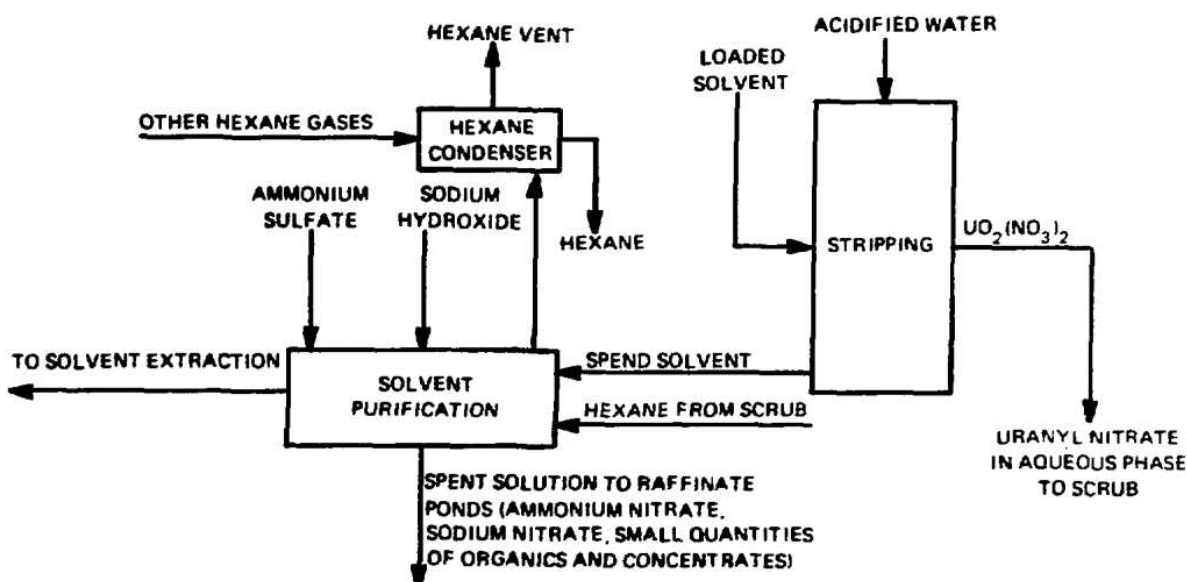


Fig. III-5. Stripping and solvent purification.

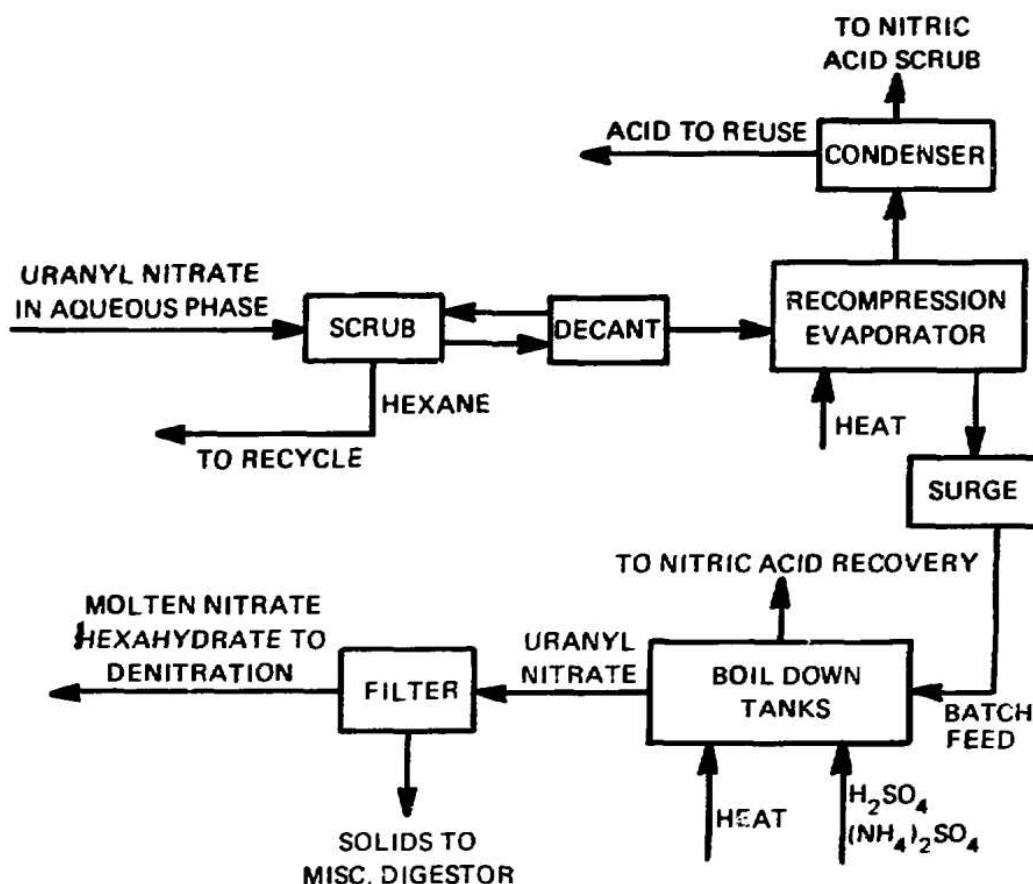


Fig. III-6. Scrubbing, decanting, and concentration.

Off-gases from the evaporator pass through a condenser and then to the central nitric acid scrubber. Acid recovered in the condenser is reused. Off-gases from the concentrator boil-down tanks are routed to the nitric acid recovery scrubber (Safety Evaluation Report-SER 1977; AP 1978).

7. Denitration and Feed Preparation

The concentrated uranyl nitrate solution, containing about 10 lb of uranium per gallon, is decomposed to uranium trioxide, oxides of nitrogen, and nitric acid vapor in four electrically heated trough-type denitrators (Fig. III-7). At the design rate, approximately 1040 lb (472 kg) per hour of NO_2 is evolved (FES 1975; AP 1978).

Denitrator off-gases pass through a water scrubber, after which the gases are combined, cooled further to condense additional nitric acid, and routed to the central nitric absorber system. There are two bubble cap column absorbers in this system, operating in parallel. In addition to gases from digestion, concentration, and denitration, the absorbers also receive vapors vented from the

nitric acid storage tanks and other vessels with NO_x off-gases. Off-gases vent through the main plant stack. Acidic liquid from the absorbers is recycled to the digestion system (AP 1978).

The uranium trioxide, now in the form of solid granules, goes to a surge bin and then to a hammer mill, where it is pulverized (Fig. III-7). After screening and air classifying, the purified material is ready for reduction (FES 1975).

Surge bin, hammer mill, and sizing section UO_3 dusts pass through the central baghouse dust collector. Fines are sent to the miscellaneous digester (discussed in Sec. B.13) (FES 1975).

8. Reduction

The purified uranium trioxide, introduced into the reactor beds through a screw feeder, is contacted and reduced with cracked ammonia in two fluid bed reactors operated in series (Fig. III-8). The reduced material (UO_2) is drawn to a surge bin where separation of the gases from the reacted pellets occurs. The off-gases contain unreacted ammonia, hydrogen, nitrogen, oxides

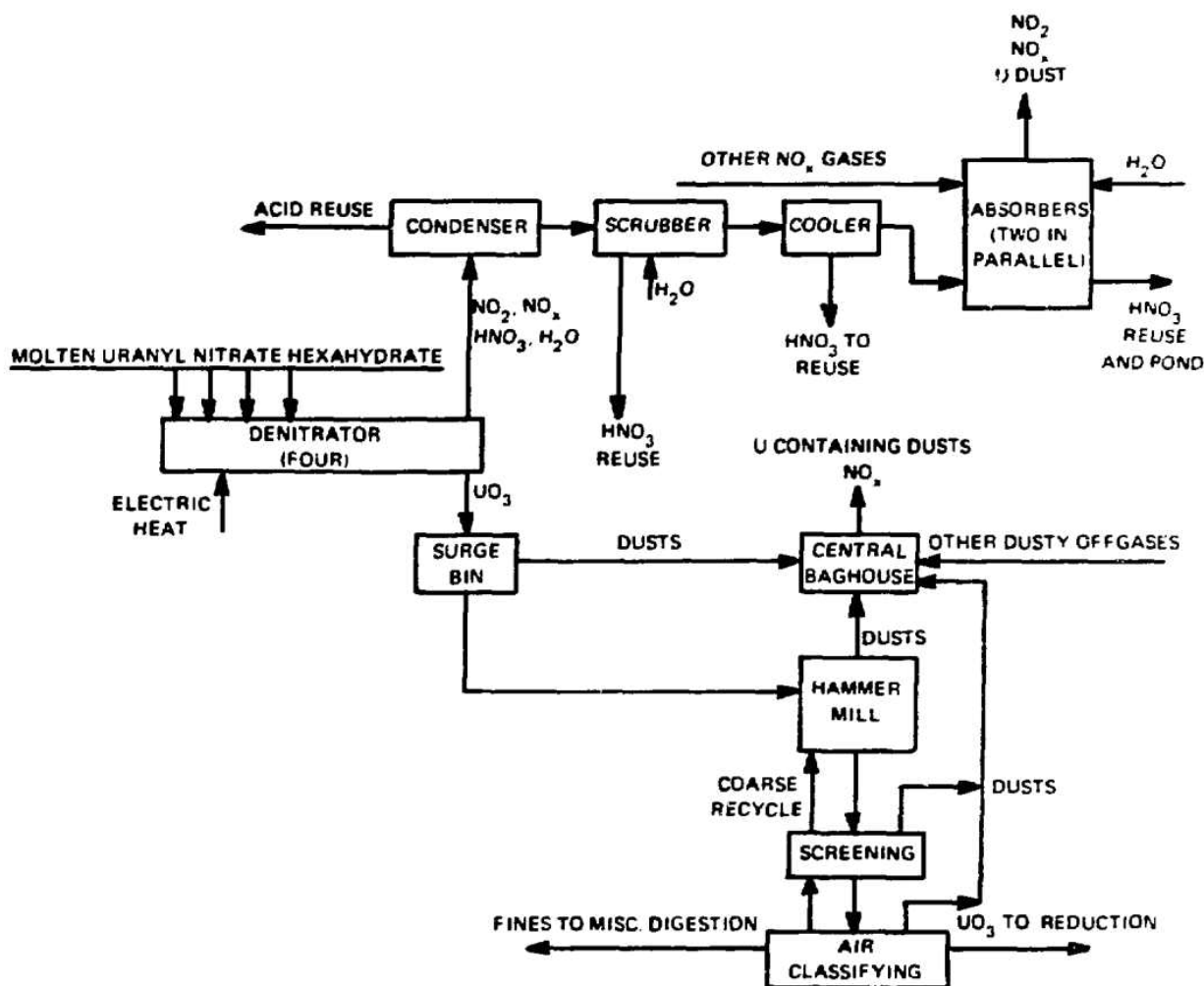


Fig. III-7. Denitration.

of nitrogen, H_2S , sulfur, UO_2 - and UO_3 -containing dusts, and water vapor. These off-gases are vented through a sintered metal filter and a backup filter. After condensation of elemental sulfur, the excess hydrogen and H_2S are oxidized, and the gas stream is vented through the steam boiler stack. The gases from this stack can contain small quantities of uranium oxides, oxides of nitrogen, SO_2 , etc. (FES 1975; AP 1978).

The ammonia dissociator used to produce the N_2 and H_2 also has a small gaseous discharge.

A central vacuum cleaner system services all process areas from concentrate sampling through reduction (Fig. III-8). The off-gases from this system discharge through a cyclone and baghouse before delivery to the main plant dust collector, which in turn consists of a cyclone and baghouse. Residues from these collection devices are sent to the miscellaneous digester (OML).

9. Hydrofluorination

The UO_2 from reduction is screw fed into the first of two stirred-bed hydrofluorinators (Fig. III-9). Here the material is fluidized with HF and reaction product gases, and converted to UF_4 . The reactants are drawn off into an interstage hopper where the solids are fed to a second-stage stirred hydrofluorinator. In this vessel, HF obtained by vaporizing anhydrous (Fig. III-9) HF is introduced to fluidize and complete the reaction to UF_4 . Solid UF_4 product is delivered to the hydrofluorination storage bin, whereas the gases are cycled to the first-stage hydrofluorinator (FES 1975).

Off-gases from the interstage hopper discharge through two carbon filters to remove UF_4 and UO_2 dusts. The residues from these filters are sent to the miscellaneous digester. The cleaned gases pass through a

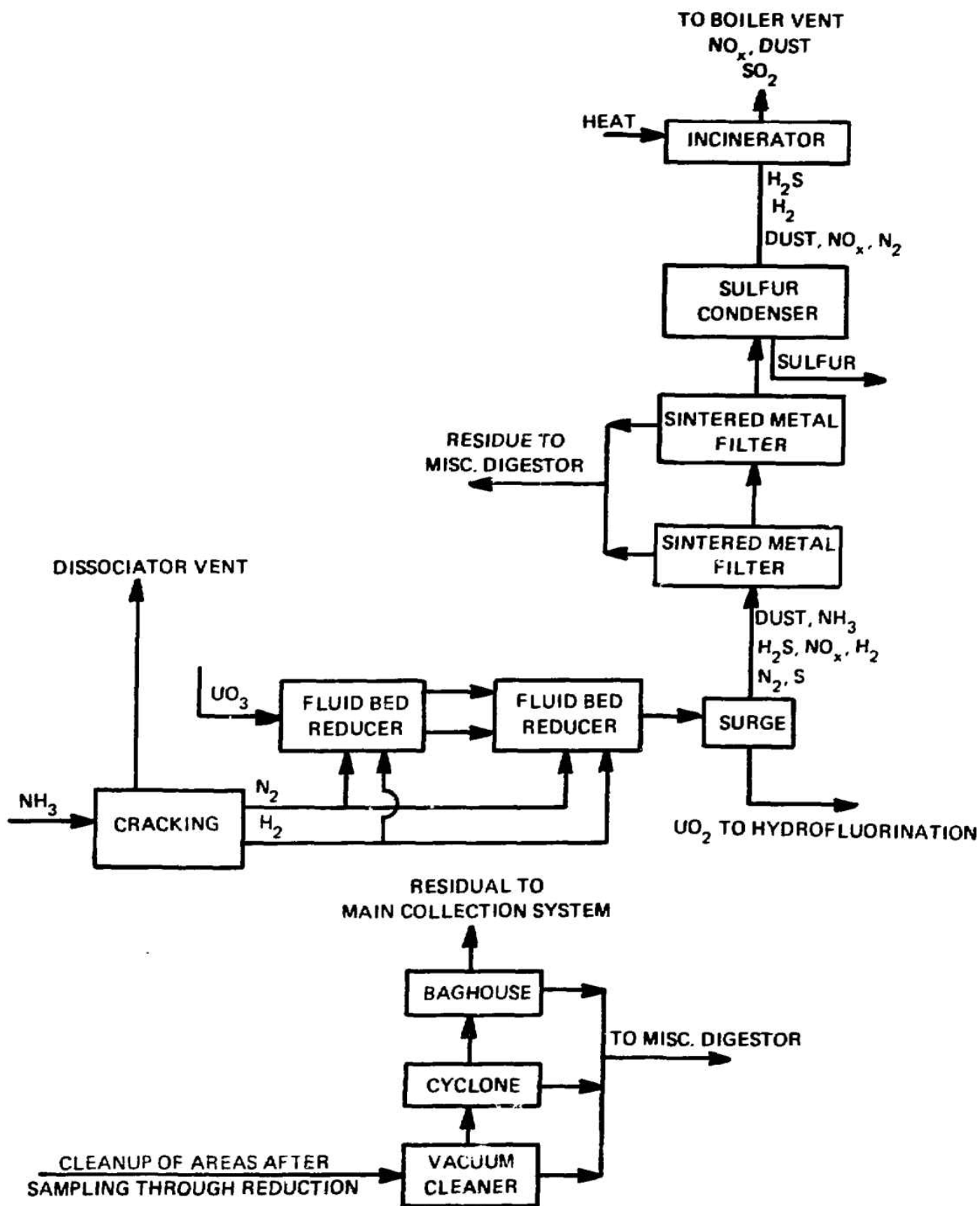


Fig. III-8. Reduction.

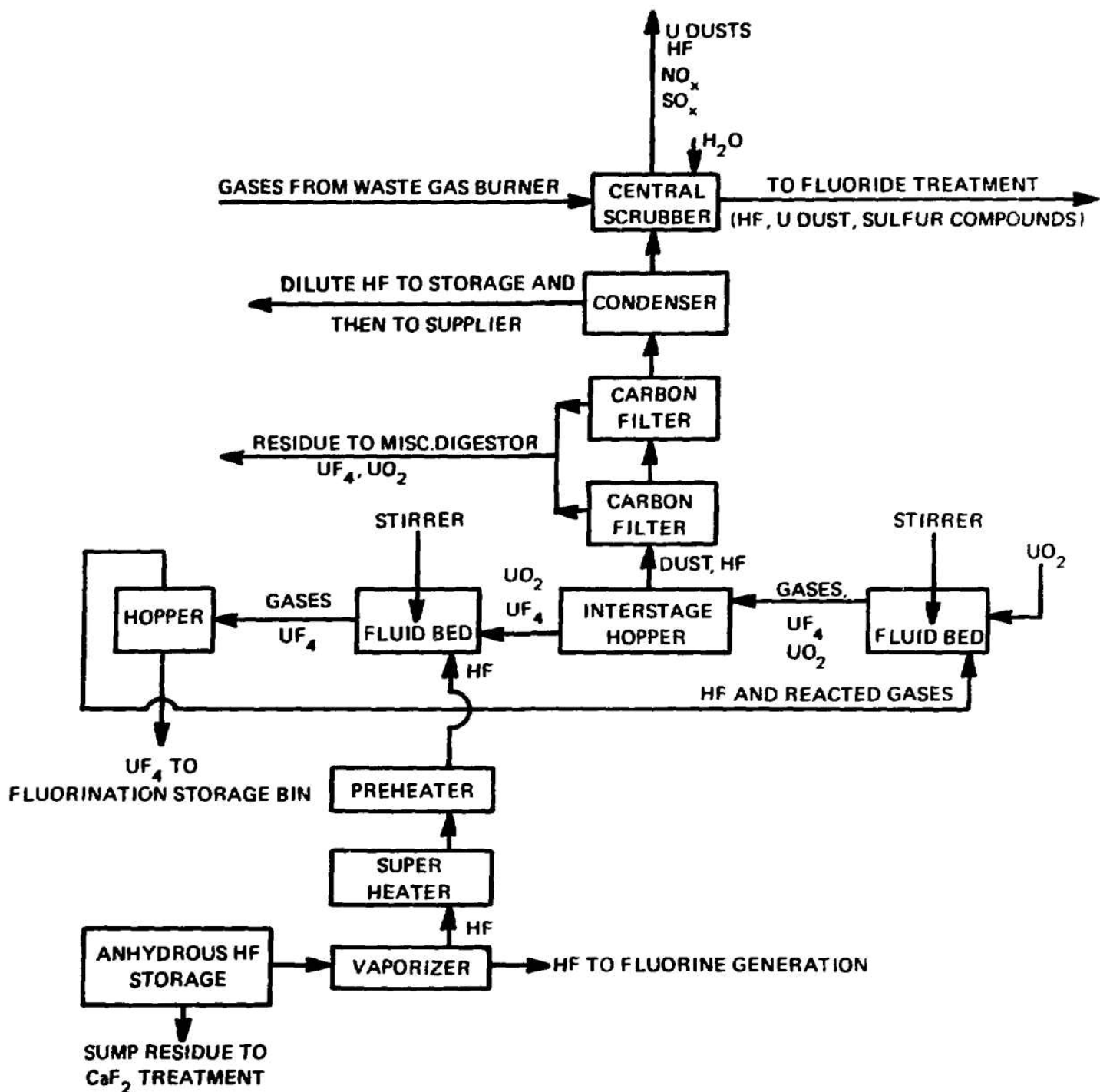


Fig. III-9. Hydrofluorination.

condenser to remove as dilute hydrofluoric acid unreacted HF and the water produced in the chemical reaction. This dilute acid is returned to the anhydrous-HF supplier (FES 1975).

The condenser off-gases are routed to the main fluorine off-gas counter-current water scrubber. In this scrubber, further particulate removal and some removal of fluorine compounds and any sulfur-containing compounds takes place. This liquid waste is sent to the fluoride treatment ponds. The scrubber off-gases contain

NO_x , HF and other fluorides, sulfur compounds, and a small quantity of uranium-containing particulates (FES 1975).

10. Fluorination

The fluorination system is a once-through fluorination process (Fig. III-10). There are two primary reactors through which the UF_4 , F_2 , and reaction products are routed. The gaseous reaction products and entrained

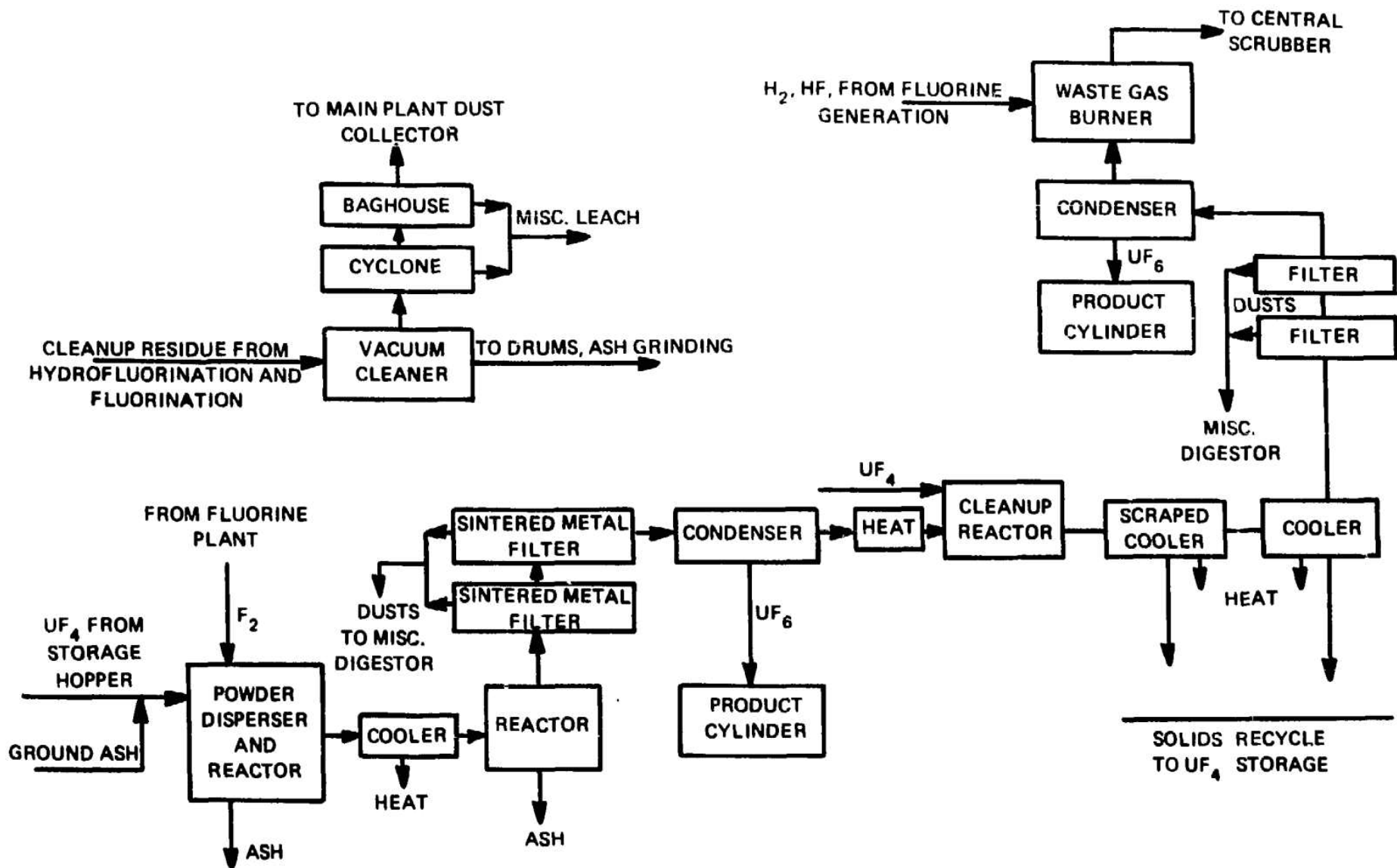


Fig. III-10. Fluorination.

solids pass through two filters to remove particulates. The filter residue is sent to the miscellaneous digester. As indicated in Fig. III-10, UF_6 is condensed from the reactor off-gas stream. This condensed product is periodically melted and drawn off into the final product cylinders (FES 1975).

Excess F_2 is used in the primary reactors to maximize the reaction to UF_6 . Any unreacted F_2 is heated and introduced to a clean-up reactor where UF_4 is also added. The F_2 reacts with the UF_4 , and UF_6 product gases again pass through two filters and a UF_6 condenser. The final off-gases are passed through a waste gas burner and finally into the main fluorine off-gas water scrubber, which has been discussed previously. Any unreacted UF_4 solids from the clean-up reactor are returned to the UF_4 storage bin (FES 1975).

The clean-up reactor is not operated all the time, in which case the off-gases from the primary reactor circuit pass directly to the waste gas burner (FES 1975).

A vacuum cleaner is used in cleaning the area and vessels located in the hydrofluorination and fluorination section. The discharge from this system passes through a cyclone and baghouse (Fig. III-10) before joining the plant gases being routed to the main plant dust collection system. The material collected in the vacuum system is drummed until it can be handled in the ash grinding system (OML).

The fluorinator ash and vacuum cleaner residue from clean-up of the hydrofluorination and fluorination sections is ground, sized, and cycled back to the fluorination towers (Fig. III-11). Any remaining uranium daughters in this "ash" are collected as dust in the fluorination

filters and ultimately rejected in the raffinate from the miscellaneous digester.

11. Fluorine Production

Fluorine is produced on-site by electrolysis of hydrogen fluoride dissolved in a fused-salt bath of potassium bifluoride (Fig. III-12). Both hydrogen and fluorine product streams are filtered (to remove any entrained electrolyte) and then compressed and cooled to remove HF [condensed HF is reused in the system (FES 1975)].

The hydrogen stream is sent to the waste gas burner (which also incinerates the final off-gases from fluorination). The waste gas burner off-gases then pass through the main plant fluorine-gas water scrubber (discussed previously).

The F_2 stream is sent to the fluorination towers (FES 1975).

The cells have to be periodically renewed. Sludges from cell cleanup and the filter residue are sent to the fluoride treatment ponds (FES 1975).

12. Miscellaneous Wastes and Effluents

The process areas in the manufacturing building are ventilated at a rate of 3000 ft³/min (1.4 m³/s). A central dust collection system is in operation, which includes collection hoods around packing glands, routinely opened equipment, and solids transfer areas. This collection system's off-gases are cleaned in a baghouse before discharge to the ambient atmosphere (OML).

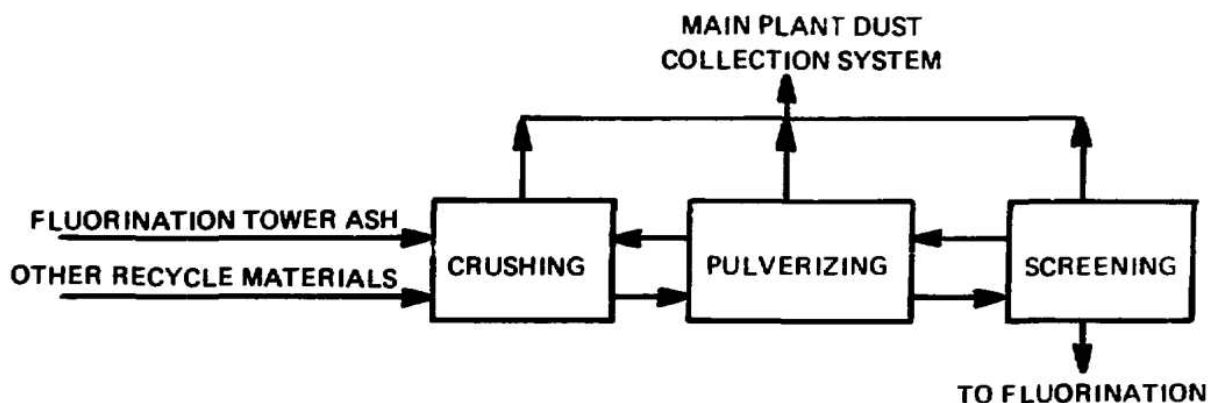


Fig. III-11. Ash grinding.

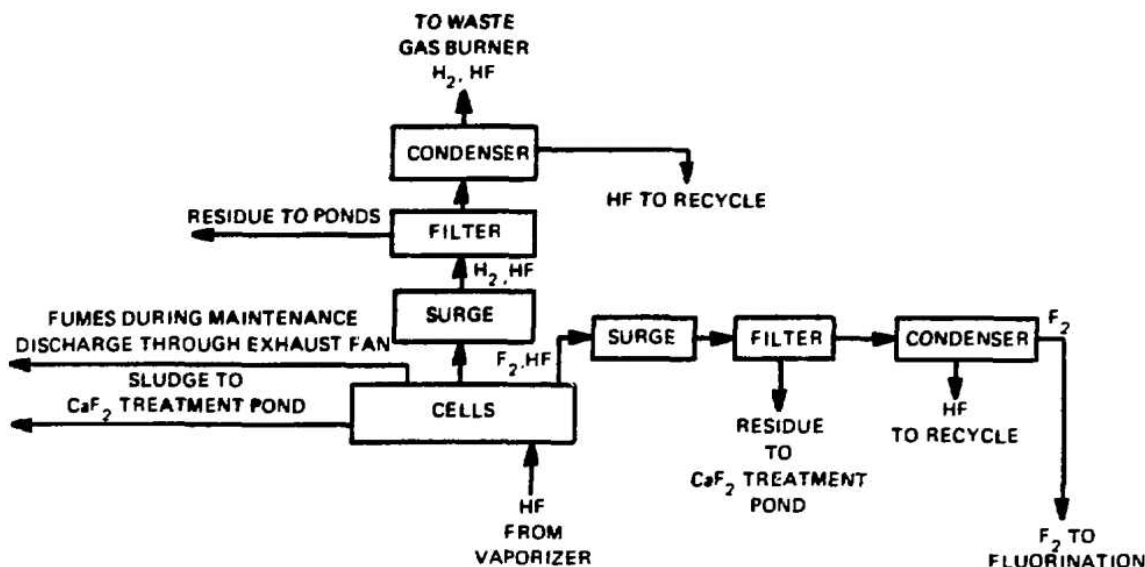


Fig. III-12. Fluorine production.

13. Miscellaneous Digester

Residues from the main plant vacuum cleaners, central baghouse dust collector, air classifier, reduction, hydrofluorination, and fluorination filters, and other miscellaneous residues containing uranium are dissolved with nitric acid in the miscellaneous digester (Fig. III-13) (FES 1975).

Off-gas from the miscellaneous digester is processed through a water scrubbing system and a caustic scrubber before being sent to the nitric acid recovery system. The scrubber liquids are sent to the raffinate ponds (SER). The impure uranyl nitrate solution then joins the uranyl nitrate solution from the main digesters before solvent extraction (SER).

14. UF₆ Cylinder Wash

Cylinders are returned to Kerr-McGee from the enrichment facilities. These cylinders contain residual UF₆ and the daughters of uranium that have "grown in" while the loaded cylinders were in storage. The daughters are generally found plated out on the cylinder walls.

After residual UF₆ is removed, the cylinder is washed with dilute nitric acid. The wash solution is filtered to remove any unleached solids and sent to the main solvent extraction circuit. Thus, the uranium daughter products, principally ²³⁴Th and ²³⁴Pa, ultimately report to the raffinate ponds.

15. Chemical Inventories

The facility maintains an inventory of uranium concentrate feed, UF₆ product, nitric acid, anhydrous ammonia, lime, anhydrous hydrogen fluoride, liquid nitrogen, hexane, and small quantities of tributyl phosphate, sulfuric acid, soda ash, aluminum hydroxide, sodium hydroxide, potassium bifluoride, lithium fluoride, ammonium sulfate, and carbon anodes (FES 1975).

There are loading and storage emissions associated with these inventories. As noted earlier, vapors from the nitric acid storage tanks are vented to the nitric acid absorbers. Gases from the HF storage tanks are vented to the central water scrubbing tower (FES 1975).

16. Summary of Discharges

Table III-1 summarizes the process discharges from each operation.

C. Available Data for Routine Releases, Disposal, and Treatment of Wastes

1. Airborne Effluents

Table III-2, taken from the Environmental Statement, indicates airborne effluents for the Kerr-McGee facility when it was designed to process 5000 tons (4535 metric tons) of uranium per year. Table III-3 indicates dis-

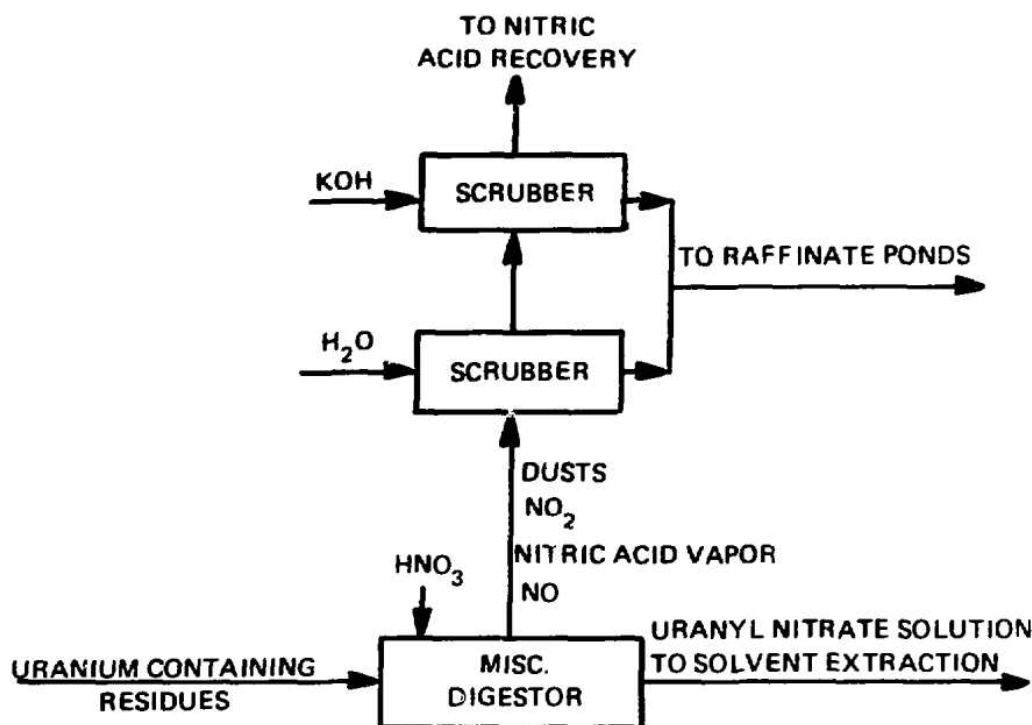


Fig. III-13. Miscellaneous digester.

charges in terms of kilograms/metric ton processed uranium. Table III-4, taken from data submitted to the Oklahoma State Department of Health, indicates the emissions expected at 10 000 tons (9070 metric tons) of uranium per year. Table III-5 indicates these discharges in terms of kilograms/metric ton processed uranium. Comparison of Tables III-3 and III-5 indicates that emissions per metric ton processed may change depending on equipment changes.

Table III-6 indicates recent data obtained from Kerr-McGee for concentrations of fluorine in soils and plants surrounding the facility.

Table III-7 indicates recent radionuclide releases to the ambient air taken from reports submitted to the NRC by Kerr-McGee (Kerr-McGee Nuclear Corporation, Environmental Report for Sequoyah Facility—ERSF), whereas Table III-8 indicates these releases as kilograms/metric ton processed.

There appear to be no currently available data on actual ambient air radionuclide concentrations at nearby residences and their solubility and particle sizes. The NRC has directed Kerr-McGee to start such a monitoring program (OML).

Calculations performed by the NRC indicate, from the limited stack emission and very limited meteorological data available, that the EPA 25-mR/yr (not including radon and radon daughters) requirement is being met by Kerr-McGee (OML).

2. Water

There are currently two discharge points at the Sequoyah facility. A continuous discharge combines decantate from the fluoride treatment ponds, sanitary waste, cooling tower water, and plant by-pass water (Fig. III-14). The other discharge is intermittent consisting of rain water run-off from fields being treated with decantate from the raffinate treatment ponds.

Table III-9 lists discharge data submitted by Kerr-McGee to the EPA as required by the NPDES permit for the continuous discharge (outfall 001). This table also converts this discharge to kilogram of contaminant per metric ton of uranium processed. (Although the exact throughput of Kerr-McGee is not publically available, an estimated production rate of 19.88 metric tons/day uranium in 1980 seems reasonable.)

Table III-10 shows similar NPDES discharge data for the field treatment run-off (outfall 002). This discharge is discussed more fully in the section on pond wastes.

Table III-11 indicates radiological liquid effluent release rates. Table III-12 converts this to release per metric ton of uranium processed. Table III-13 lists water sampling data for intake and discharge; Table III-14 lists water data up- and down-stream for 1972, and Table III-15 indicates the same location data for 1974. Table III-16 indicates the plant water balance.

TABLE III-1
SUMMARY OF DISCHARGES

Process	Discharge	
	Air	Ponds
Sampling	Dust and radon	Wash water (concentrate)
Digestion	NO _x	Wash water (concentrate, nitric acid)
Solvent extraction treatment and stripping	Hexane, TBP, NO _x	Plant washdown water and raffinate (U, U daughters, Mn, As, Se, V, Mo, Si, and S compounds, ammonium nitrate, sodium nitrate, organics, and dilute nitric acid)
Concentration	NO _x	Plant wash water and weak acids
Denitration and feed preparation	NO _x , Dust	Plant wash water and weak acids
Reduction	NO _x , N ₂ , H ₂ O, U oxides, SO ₂	Plant wash water
Hydrofluorination	HF, NO _x , SO _x , Dust	Scrubber water and plant wash water (F, U, S compounds)
Fluorination and ash grinding	F ₂ , HF, dust	Scrubber water and plant wash water (F, U, S compounds)
Fluorine production	H ₂ O, HF, H ₂	Sludges and filter residue
Miscellaneous digester	Dusts, NO _x , fluoride compounds	Potassium compounds, nitrates, uranium, fluoride compounds
Cylinder wash		(Liquid-to-solvent extraction; ²³⁴ Th and ²³⁴ Pa decay in discharge to raffinate pond)
Chemical inventories	Hexane, HF, NH ₃ , lime dust, radon, nitric acid	

TABLE III-2

SUMMARY OF AIRBORNE EFFLUENTS AT DESIGN THROUGHPUT 5000 T/YR
(Quantities in Metric Tons per Month)

<u>Effluent Source</u>	<u>Uranium</u>	<u>Nitrogen Dioxide</u>	<u>Sulfur Dioxide</u>	<u>Fluorides</u>	<u>Water</u>	<u>Nitrogen</u>	<u>Oxygen</u>	<u>Hexane</u>
Sample preparation room	1×10^{-5}							
Absorber tail gas		4.6			280	540	160	
Reduction off-gas			1.5		91	1700	470	
HF scrubber	2×10^{-4}			0.006	62	3700	1100	
Fluorine vent				0.095 ^b				
Dust collectors	1.6×10^{-3}							
Fluorine cell rework				0.30				
Natural gas combustion ^a		5.8			2800	18 000	480	
Process building roof vents	3.8×10^{-3}							
Hexane vent								8.8
Total Air Stream	5.61×10^{-3}	10.4	1.5	0.131	3233	23 940	2210	8.8

^aBased on combustion of 63.6×10^6 ft³ of natural gas per month with 10% excess air.

^bIncludes elemental fluorine.

Source: FES 1975.

TABLE III-3

**AIRBORNE EFFLUENTS (NONRADIOLOGICAL)
AT 4535 METRIC TON/YR (OMITS COMBUSTION)***

Discharge	Metric T/Yr	Kg/Metric T Uranium
NO ₂	55.2	12.17
SO ₂	18.0	3.97
Fluorides	1.57	0.35
N ₂	71 280.0	15 720.00
Hexane	105.6	23.29

**COMBUSTION EMISSIONS
FOR GAS-FIRED BOILERS**

NO ₂	69.6	15.35
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*Combustion emissions will depend on fuel used.

TABLE III-5

**AIRBORNE EFFLUENTS (NONRADIOLOGICAL)
AT 9070 METRIC TON/YR**

Discharge	Metric T/Yr	Kg/Metric T Uranium
NO _x	223.2	24.6
SO ₂	49.56	5.46
Fluoride	2.09	0.23
Fluoride (ground)	0.384	0.04
Hexane	168.0	18.52

TABLE III-4

**AIRBORNE EFFLUENT SUMMARY
Level of Production**

Present Level = 5000 Short Tons U/Yr, Expanded Level = 10 000 Short Tons U/Yr

Item	Metric Tons per Month Level of Production		Grams per Second Level of Production		Highest Concentration, µg/m ³ Distance: 1/2 mile Level of Production		Ambient Air Quality Standards (µg/m ³)
	Present	Expanded ^a	Present	Expanded ^b	Present	Expanded	
NO _x	10.4 ^b	18.6	3.96	7.07	1.98	3.54 WSW	100 ^d
SO ₂	1.51 ^c	4.13	0.574	1.56	0.287	0.78 WSW	60 ^e
Fluoride	0.101 ^c	0.174	0.12	0.066	0.115	0.252 SW	0.5 ^f
Fluoride (ground)	0.030 ^c	0.032	0.004	0.012			
Hexane	8.8 ^c	14.0	3.69	5.33			15.88 g/sec ^g

^aInformation Source: Table II - page 24, June 1975, Environmental Information on Expansion.

^bInformation Source: Historic Records - 1974 - No Allow. for Boiler Gen.

^cInformation Source: Table XI (Revised) - page 12, Jan 1973, App. Environmental Report Supplemental No. 2.

^dEPA National Primary and Secondary Ambient Air Quality Standard.

^eEPA National Secondary Ambient Air Quality Standard.

^fState of Washington Ambient Air Fluoride Standard.

^gOklahoma State Health Department, Air Quality Services, Environmental Service - Guidelines for Interpretation and Enforcement of Regulation No. 15 (15.33).

TABLE III-6

FLUORIDE CONCENTRATIONS IN SOIL AND VEGETATION

	Fluoride ($\mu\text{g/g}$)	
	April	October
Soil Location^a		
1000 ft South	284	130
1000 ft West	110	170
1000 ft North	213	85
1000 ft East	156	140
6000 ft South	111	180
6000 ft West	280	150
6000 ft North	207	410
6000 ft East	249	120
Vegetation Location^a		
1000 ft South	44	31
1000 ft West	10	122
1000 ft North	9	34
1000 ft East	29	48
6000 ft South	17	29
6000 ft West	7	26
6000 ft North	10	28
6000 ft East	12	33

^aDistance from the plant.

Source: Kerr-McGee Corp.

To improve the data base on the effects of the water outfall discharge into the Illinois River, the NRC asked Kerr-McGee for an environmental monitoring program that would include the analyses of bottom sediments and benthic populations. The results of the population study for 1980 (as supplied by Kerr-McGee) are given in the Appendix.

3. Heat Load Estimate

Heat is discharged both as a discharge-water temperature rise (see Table III-9) and as evaporation. While running at a throughput of 10 000 tons uranium/year (9070 metric tons), the plant dissipates approximately 68 million Btu/h (19.72 million watts) through evaporation and drift loss from the cooling tower and 5 million Btu/h (1.45 million watts) through

the cooling water discharge. Other dissipation processes include pond evaporation and convection. The total heat load is approximately 134 million Btu/h (39 million watts). This indicates a heat dissipation load of approximately 0.136×10^{12} joules per metric ton of uranium processed (FES 1975).

4. Ponds and Sludges

a. Raffinate Ponds. Figure III-15 illustrates the typical waste inputs and their expected compositions discharged to the two raffinate ponds. Presently, anhydrous ammonia is added to the incoming liquors to maintain a pH of 5 to 8 to precipitate metals and other contaminants. The neutralized raffinate pond decantate is then pumped to a mixing basin where barium is added to remove radium (ERSF). The barium-radium precipitate is stored as sludge.*

An evaporator is used to increase evaporation in the holding pond. In addition, after radium removal, liquid is discharged as a fertilizer onto about 400 acres of nearby fields (OML). Data on water quality from run-off of these fields is given in Table III-10. The raffinate decantate placed on the fields has been reported by Kerr-McGee to the NRC to have a pH of approximately 8.5 and contain 1 pCi/l of ^{226}Ra , $1.34 \times 10^{-7} \mu\text{Ci/ml } U_{\text{nat}}$, and $50 \times 10^{-9} \mu\text{Ci/ml } ^{230}\text{Th}$ (FES 1975). These data can be compared with $2.0 \times 10^{-5} \mu\text{Ci/ml } U_{\text{nat}}$, $1.4 \times 10^{-6} \mu\text{Ci/ml } ^{226}\text{Ra}$, and $0.75 \times 10^{-6} \mu\text{Ci/ml } ^{230}\text{Th}$ for neutralized raffinate also submitted as data by Kerr-McGee. Kerr-McGee reported treated raffinate as containing 0.3 mg/l arsenic (FES 1975).

For raffinate sludges, Kerr-McGee has reported to NRC that the radionuclide content of the raffinate ponds as of December 1973 was 8625 kg of uranium, 0.091 Ci of radium, and 0.157 Ci of thorium. Assuming 10 884 metric tons processed up to that time, indications are that 0.79 kg of uranium is discharged to the ponds per metric ton of uranium processed (FES 1975). Table III-17 provides data supplied by Kerr-McGee for the 1980 average of impurities in incoming concentrate. These contaminants, in general, ultimately report to the raffinate pond sludge.

Table III-18 reports recent data submitted to NRC concerning raffinate sludge composition (ERSF).

During the period when the raffinate ponds were unlined, seepage was detected. More details on the

*This information provided by W. J. Shelley, Kerr-McGee, June 1981.

TABLE III-7

RADIOLOGICAL AIR EFFLUENTS RELEASE RATES
(μCi)

Period	Gross Alpha	$^{238}\text{U}^a$	^{235}U	^{234}U	^{230}Th	^{226}Ra
Jan-June 1976	24 000	12 067	550	11 374	7	2
July-Dec 1976	21 200	10 659	486	10 047	6	2
Jan-June 1977	25 340	12 741	580	12 009	8	2
July-Dec 1977	45 800	23 028	1049	21 705	14	4
Jan-June 1978	20 490	10 302	469	9711	6	2
July-Dec 1978	51 300	25 794	1175	24 311	15	5
Jan-June 1979	50 000	25 140	1145	23 695	15	5
July-Dec 1979	108 600	93 100 ^{b,c}			1744	840
Jan-June 1980	86 300	83 800 ^b			1503	900

^aThe licensee analyzed the plant dust for isotopic uranium and ^{230}Th and ^{226}Ra ; the ratio of individual nuclides for the contribution of gross alpha is as follows:

$^{238}\text{U}; ^{235}\text{U}; ^{234}\text{U}; ^{230}\text{Th}; ^{226}\text{Ra} = 50.28:2.29:47.39:0.03:0.01$.

^bReported as U_{nat} .

^cOne batch release 4.47×10^{-3} Ci.

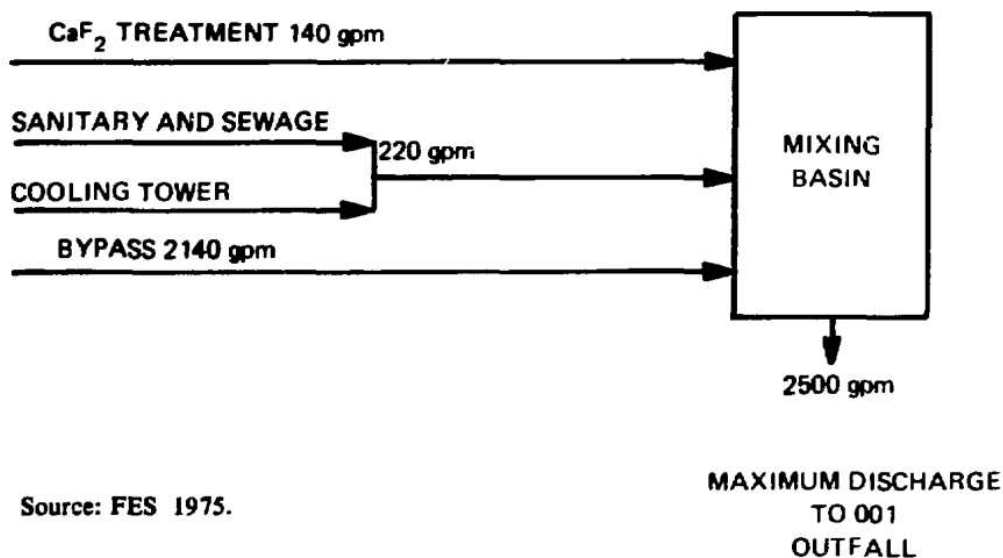
Source: Reports from Kerr-McGee to NRC.

TABLE III-8

**RADIOLOGICAL AIR EFFLUENT RELEASE RATES AS A
FUNCTION OF THROUGHPUT* (ALL UNITS μCi)**

	1976	1977	1978
MTU Throughput	3537	4173	5533
Gross Alpha	45 200	71 140	71 790
Gross Alpha/(MTU)	12.78	17.05	12.97
^{238}U	22 726	35 769	36 096
$^{238}\text{U}/(\text{MTU})$	6.43	8.57	6.52
^{235}U	1036	1629	1644
$^{235}\text{U}/(\text{MTU})$	0.29	0.39	0.30
^{234}U	21 421	33 714	34 022
$^{234}\text{U}/(\text{MTU})$	6.06	8.08	6.15
^{230}Th	13	22	21
$^{230}\text{Th}/(\text{MTU})$	0.004	0.01	0.003
^{226}Ra	4	6	7
$^{226}\text{Ra}/(\text{MTU})$	0.001	0.001	0.001

*MTU is metric tons uranium throughput.



Source: FES 1975.

Fig. III-14. Sources of the 001 outfall.

monitoring wells and water quality of the seepage are given in the Final Environmental Statement.

At present, one unlined raffinate pond is full. However, all active discharge is to lined ponds.*

Kerr-McGee recently submitted to NRC a plan to dispose of the raffinate sludges. A portion of this submittal is given below.

"At the current plant production capacity of 9,090 MTU per year, sludge is generated at a rate of 2.3 million gallons per year. It is estimated that there was a total of 10 million gallons of sludge in inventory in pond 2 at the end of 1979. At the projected end of plant life, in the year 2000, an estimated 56 million gallons will have been generated for burial.

"The program for removal and disposition of the radioactive sludges consists of the following:

"1. The sludge in pond 1 is to be transferred by a barge-mounted pump to pond 2 to permit modification of pond 1 to become Clarifier A as approved in a previous license amendment.

"2. The inventory of sludge in pond 2 and sludge subsequently deposited in Clarifier A will be transferred at the rate of 20,000 gallons per day to large cone-bottom dewatering tanks adjacent to Clarifier A where excess water will be removed and returned to Clarifier A.

"3. The dewatered sludge (approximately 60% H₂O) will then be pumped from the dewatering tanks via a pipeline through a booster station to the disposal site approximately one mile away.

"4. At the disposal site the sludge will enter a ribbon blender and be mixed with an equal volume of Portland cement and/or another material with equal or better radon stabilization characteristics. (Experiments with clay additions as a diluent have shown some promise for additional radium stability.)

"5. The sludge-cement mixture will flow by gravity to 4' x 4' x 8' forms erected in the disposal pit.

"6. After solidification, the blocks will be covered with polyethylene film to minimize leaching of nitrate and radium by rainwater.

"7. The disposal pit will be constructed in phases to permit layering of the solidified sludge in a running brick pattern. This method of placement will permit isolation of run-off water from clean rain water and at the same time permit surface reclamation of each completed block pattern as the solidification progresses.

"The Disposal Pit

The initial excavation for sludge disposal will be approximately 400' x 500' x 60' deep with side slopes of 3H to 1V. The sides and bottom of the

*This information provided by William Nixon, NRC, April 1981.

TABLE III-9

KERR-McGEE 001 OUTFALL WATER QUALITY

1980 Sampling Period	Av Flow MGD	Av Flow $m^3/s \times 10^{-2}$	kg/day						mg/l Max Oil & Grease	mg/l Av Oil & Grease	°F Min Temp	°F Max Temp	Min pH	Max pH
			Max TSS	Av TSS	Max F	Av F	Max Nitrate	Av Nitrate						
Sept	3.19	13.98	40.0	13.0	7.6	5.1	57.0	24.0	4.0	1.0	62	72	2.0 ^a	8.3
Aug	3.21	14.06	52.0	13.0	15.0	7.0	31.0	16.0	3.0	0.7	64	70	6.7	8.6
July	3.26	14.28	61.0	20.0	10.0	5.6	36.0	25.0	2.0	0.4	62	70	6.8	8.2
June	3.38	14.81	50.0	20.0	11.0	5.5	36.0	23.0	1.0	0.5	62	70	7.1	8.6
May	3.60	15.77	25.0	13.0	15.0	9.0	31.0	25.0	4.0	2.0	57	66	7.1	8.6
April	3.49	15.29	35.0	15.0	35.0 ^a	7.0	22.0	17.0	5.0	2.0	50	59	6.9	9.2 ^a
March	3.40	14.90	220.0	32.0	17.0	5.0	23.0	16.5	2.0	1.0	50	58	7.3	8.9
Feb	3.41	14.94	47.0	13.0	17.0	6.0	17.0	13.0	4.0	1.0	50	55	7.4	9.2 ^a
Jan	3.32	14.54	39.0	20.0	15.0	5.0	29.0	19.0	5.0	2.5	47	57	7.1	8.8
Average	3.36 ^c	14.72		17.67		6.24		19.83						
Average/MTU ^b				0.89 kg		0.31 kg		1.00 kg						

^aNoncompliance.^bAssuming 8000 T/year = 7256 MT/yr = 19.88 MT/day.^cAverage flow 2333 gpm.

Source: NPDES data.

TABLE III-10

KERR-McGEE 002 OUTFALL WATER QUALITY

1980 Sampling Period	Max Flow MGD	Max Flow m ³ /s × 10 ⁻²	Av TSS mg/l	Av Dissolved ²²⁶ Ra pCi/l	Av Total ²²⁶ Ra pCi/l	Av Ammonia mg/l	Av Nitrate mg/l	Max pH	Min pH
Sept	No flow								
Aug	No flow								
July	0.43 ^a	1.88	28.0	0.14	0.15	<0.2	0.6	6.8	6.7
June	0.03 ^b	0.13	79.0 ^c	NA	NA	<0.2	1.3	6.6	7.2
May	No flow								
April	No flow								
March	No flow								
Feb	No flow								
Jan	No flow								

^a24 h only.^b4 days only.^cNoncompliance.

Source: NPDES

TABLE III-11

RADIOLOGICAL LIQUID EFFLUENTS
RELEASE RATES

Period	Gross Alpha (Ci)	Natural Uranium (Ci)	²³⁰ Th (μCi)	²²⁶ Ra (μCi)
Jan-June 1976	0.548	0.492		
July-Dec 1976	0.480	0.490		
Jan-June 1977	0.712	0.610		
July-Dec 1977	1.195	0.968		
Jan-June 1978	1.105	0.885		
July-Dec 1978	0.894	0.825		
Jan-June 1979	1.519	1.351		
July-Dec 1979	1.449	1.290	103.3	113.1
Jan-June 1980	1.751	1.496	189.0	214.0

Source: Kerr-McGee reports to NRC.

TABLE III-12

RADIOLOGICAL LIQUID EFFLUENT RELEASE
RATES AS A FUNCTION OF THROUGHPUT

	1976	1977	1978
Ton Uranium Throughput	3900	4600	6100
Metric Ton Uranium Throughput	3537	4173	5533
Gross Alpha μCi × 10 ⁴	1.028	1.907	1.999
Gross Alpha (μCi) per Metric Ton	290.64	456.99	361.29
U _{net} μCi × 10 ⁴	0.982	1.578	1.710
U _{net} μCi per Metric Ton	277.64	378.15	309.05

TABLE III-13

CHEMICAL PARAMETERS OF INTAKE WATER AND DISCHARGE
DAILY/AVERAGE CONCENTRATIONS, mg/l

Parameter	Untreated ^a Intake	Combined ^a Discharge	Suggested ^b Criteria	U.S.P.H.S. ^c MPC
Alkalinity (as CaCO ₃)	73-94	99	120	—
B.O.D. 5-day	2	2	1.0 - 3.0(max)	—
Chemical oxygen demand	10	10	—	—
Total solids	138	235	—	—
Total dissolved solids	137	232	1000	500
Total suspended solids	6	20	—	—
Total volatile solids	50	50	—	—
Ammonia (as N)	1.4	<1	0.1	—
Kjeldahl nitrogen	1.3	<1	10	—
Nitrate (as N)	0.57	3.5	10	10 ^d
Phosphorus total	0.04	0.3	—	—
Color (Pt-Co units)	25	15	20 - 70	15
Turbidity (Jackson units)	7	8	0 - 40	5
Total organic carbon	1.7	1.0	—	—
Total hardness	89	110	—	—
Phosphorus (ortho)	<0.1	<0.1	—	—
Sulfate	6.6	16	250	250
Sulfide	<0.1	<0.1	—	—
Chloride	5	50	50	250
Fluoride	0.1	1.54	1.5	0.7 - 1.2 1.4 - 2.4*
Aluminum	0.18	0.40	—	—
Barium	0.1	0.125	—	1.0*
Cadmium	<0.01	<0.01	0	0.01*
Cyanide	0	0	0	0.01
Calcium	32	46	—	—
Chromium	0.075	0.060	0	0.05*
Copper	0.033	0.090	3.0	1.0
Iron	0.85	1.0	0.3	0.3
Lead	<0.01	<0.01	—	0.05*
Magnesium	2	2	—	—

^aReported by Licensee to EPA Region VI in Permit Application No. OK-076-0Y12-000111, Revised February 1, 1973.

^bSuggested Criteria of Raw Water Quality for the State of Oklahoma (for Municipal use). Ref. No. 1845, "Water Quality Criteria," California State Water Resources Control Board Publication 3A (Reprint, December 1971).

^cUS Public Health Service Drinking Water Standards 1962. Values reported are "suggested limit that should not be exceeded" except starred values, which are listed under "Cause for Rejection."

^dActually listed as 45 mg/l nitrate.

Source: FES 1975.

TABLE III-13 (cont)

Parameter	Untreated ^a Intake	Combined ^a Discharge	Suggested ^b Criteria	U.S.P.H.S. ^c MPC
Manganese	0.02 – 3.3	1.3	—	0.05
Mercury	<0.001	<0.001	—	—
Potassium	1	1	—	—
Sodium	3	35	0 – 10	—
Tin	<0.01 – 0.7	0.04	—	—
Titanium	<0.01	<0.01	—	—
Zinc	0	0.04	—	5.0

TABLE III-14

**EFFECT OF LIQUID EFFLUENT ON NITRATE
AND FLUORIDE CONTENT OF SURFACE WATERS**

Water Sample Source	Period Jan-Oct 1971 ^a			
	Nitrate		Fluoride	
	Average Concentration (ppm)	% of USPHS (MPC) ^b	Average Concentration (ppm)	% of USPHS (MPC) ^b
Raw water ^c	0.40	0.89	0.53	27.9
Combined effluent ^c	1.36	3.02	0.76	40.0
Illinois River				
Upstream	0.24	0.53	0.59	31.1
Downstream	0.24	0.53	0.64	33.7
Arkansas River				
Upstream	0.28	0.62	0.81	42.6
Downstream	0.18	0.40	0.80	42.1

^aData are average analyses of monthly composites.

^bUS Public Health Service Drinking Water Standards 1962:

 Nitrate 45 ppm (limit that should not be exceeded);

 Fluoride 0.7 - 1.2 ppm (limit that should not be exceeded)

 Fluoride 1.4 - 2.4 ppm (cause for rejection)

 Fluoride 1.9 ppm used for calculation.

^cMonthly composite of daily samples. Others sampled weekly.

Source: FES 1975.

TABLE III-15

**1974 ENVIRONMENTAL WATER SAMPLES SURFACE
UNITED STATES TESTING RESULTS
RADIOACTIVE UNITS, α , β , Ra, U - $\mu\text{Ci}/\text{ml} \times 10^{-3}$
CHEMICAL UNITS NO_3 ,^a F - ppm**

Location	Analysis	January	February	March	April	May	June	July	August	September	October
2201 Illinois River Upstream	Nitrate	0.2	0.2	0.5	0.8	0.6	0.2	0.5	0.3	0.2	0.2
	Fluoride	<0.5	<0.5	<0.5	<0.5	0.4	0.8	0.5	0.9	0.7	0.2
	Gross α	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.7	<0.8	—	—
	Gross β	<2.2	<2.5	<2.0	<2.5	<2.6	<1.9	<1.5	<1.6	—	—
	Uranium	3.2	2.7	0.7	<0.7	0.7	<0.5	<0.5	<0.5	1.1	<0.5
	²²⁶ Ra			0.007			0.03				
2202 Illinois River Downstream	Nitrate	0.6	<0.2	0.4	0.7	0.4	0.2	0.5	0.3	0.1	0.2
	Fluoride	<0.5	<0.5	<0.5	0.7	0.8	0.2	0.3	0.3	0.6	0.2
	Gross α	<0.8	<0.8	<0.8	<0.8	1.5	<0.8	0.9	2.0	—	—
	Gross β	<2.2	<2.5	<2.0	<2.5	<2.6	<1.9	<1.5	<1.6	—	—
	Uranium	5.2	5.4	0.9	0.8	0.6	<0.5	0.7	0.7	0.5	<0.5
	²²⁶ Ra			<0.007			0.014				
2203 Arkansas River Upstream	Nitrate	0.7	0.2	0.8	0.8	<0.1	0.5	0.6	0.3	0.4	0.4
	Fluoride	<0.5	<0.5	<0.5	<0.5	0.4	0.7	0.3	0.4	1.8	0.3
	Gross α	<0.8	<0.8	<0.8	2.1	<0.8	<0.8	<0.7	<0.8	—	—
	Gross β	<2.2	<2.5	<2.0	<2.5	<2.6	<1.9	<1.5	<1.6	—	—
	Uranium	3.0	3.0	0.7	<0.7	<0.5	<0.5	<0.5	<0.5	0.5	<0.5
	²²⁶ Ra			0.024		<0.007					
2204 Arkansas River Downstream	Nitrate	0.8	0.1	0.8	0.9	1.9	0.5	0.6	0.4	0.5	0.4
	Fluoride	<0.5	<0.5	<0.5	<0.5	0.5	0.3	0.3	0.3	0.4	0.3
	Gross α	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.7	1.4	—	—
	Gross β	<2.2	<2.5	<2.0	<2.5	7.1	<1.9	<1.5	<1.6	—	—
	Uranium	3.7	4.0	0.7	1.3	<0.5	0.7	0.5	2.9	1.0	<0.5
	²²⁶ Ra			0.021			0.010				

^aNitrate reported as nitrogen.

Source: FES 1975.

TABLE III-16

**WATER BALANCE FOR SEQUOYAH
AT 10 000 TON U/YR (9070 MTU)**

Source	Gal/Min
Received	2800
To plant process	660
Bypass	2140
Loss by evaporation	300
Plant discharge ^a	360
Outfall	2500

^aPlant discharge includes sewage lagoon overflow, sanitary wastes, decantate from the fluorine precipitation treatment system, and cooling tower water discharge.

Source: FES 1975.

opening will be provided with a 5-foot compacted clay liner (permeability of 10^{-9} cm/sec) covered by a 30-mil reinforced Hypalon membrane liner. The Hypalon liner is recommended by the manufacturer for prevention of diffusion of nitrate ion through the clay. The disposal pit will be constructed in phases with a barrier wall provided to separate possibly contaminated water from relatively clean rainwater. The phased approach to pit construction will provide minimal surface disturbance and permit early land reclamation of phases as they are completed. The land reclamation will consist of backfilling and topsoil replacement and reseedling to restore native vegetation."

(Kerr-McGee Nuclear Corporation Environmental Report for Sequoyah Facility Raffinate Sludge Disposal).

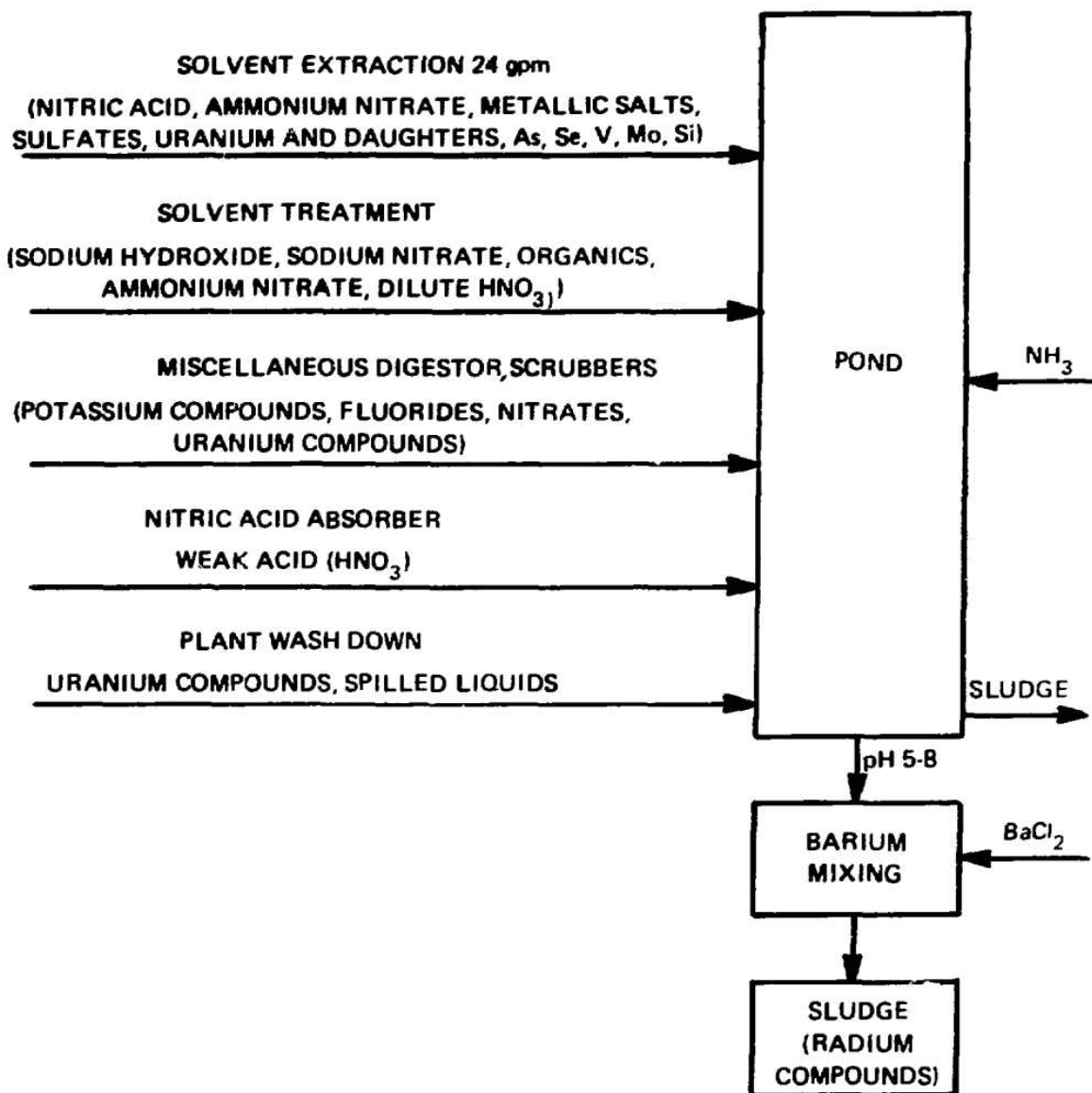


Fig. III-15. Discharge to raffinate ponds.

In addition to the proposal made to the NRC for on-site disposal of raffinate sludges, Kerr-McGee is also seeking approval from the licensing staff of the State of New Mexico to dispose of the sludge on the Kerr-McGee Ambrosia Lake uranium mill tailings pile located near Grants, New Mexico. The material would be transported to New Mexico primarily as a back-haul on trucks delivering concentrate slurry to the UF_6 plant.*

b. Fluoride Treatment Ponds. Figure III-16 illustrates the various waste inputs and their expected composition going to the fluoride treatment ponds.

As shown in Fig. III-16, slaked lime is added to the inflow and reacts with the dilute HF and other chemical compounds to produce calcium fluoride/calcium hydroxide/calcium sulfate sludge, which settles out in the sludge pit (OML). About 600 tons (544 metric tons) of sludge are generated each year (FES 1975). Over the life of the plant, it is estimated that 18 200 metric tons of calcium fluoride sludge containing 2.5 metric tons of uranium will require disposal (FES 1975).

Recent Kerr-McGee data indicate that 3762 metric tons of CaF_2 sludge containing an activity of $33 \mu Ci/ft^3$ have been buried on-site in four locations. At present, however, all generated sludge is being held in retention

*Letter from W. J. Shelley, Kerr-McGee to Al Topp, State of N.M., Aug. 7, 1981.

TABLE III-17

CONCENTRATE IMPURITIES
1980 Average of all Lots Sampled

Impurity	Values in Per Cent on a Uranium Basis ^a
Nitric Acid	
insoluble U ^a	0.02
Molybdenum (Mo)	0.08
Vanadium (V)	0.05
Calcium (Ca)	0.25
Thorium (Th)	0.06
Zirconium (Zr)	<0.03
Boron (B)	<0.01
Phosphorus (P)	0.06
Halogens (Cl, Br, I as Cl)	0.13
Fluoride (F)	0.01
Carbonate (CO ₃)	0.07
Sulfur (S)	1.00
Arsenic (As)	<0.05
Sodium (Na)	0.72
Magnesium (Mg)	0.09
Iron (Fe)	0.53
Silicon (Si)	0.53

^aSequoyah Facility Lab results. ²²⁶Ra is not routinely run.

Source: Kerr-McGee.

ponds until NRC approves a license amendment for burial.*

Sulfuric acid is added to achieve a pH between 6-8, and the liquid is fed to a clarifying lagoon (FES 1975). The discharge from the clarifying lagoon, approximately 140 gpm (0.00883 m³/s), joins the sanitary discharge, cooling tower discharge, and bypass water for discharge at the 001 outfall.

5. Solid Nonsludge Wastes

Nonradioactive combustible materials, such as boxes, crates, paper, and rags, were burned in an open pit incinerator whose off-gases discharged directly to the ambient air. Ashes and unburned residue were buried in the pit. Other types of combustible nonradioactive

*This information provided by W. J. Shelley, Kerr-McGee, June 1981.

TABLE III-18

CHEMICAL CONSTITUENTS OF WET SLUDGE

Element	Percent
Al	0.15
As	0.012
B	<0.013
Ca	0.10
Cl (incl Br & I)	0.005
C (from CO ₂)	0.02
Fe	0.25
F	0.001
K	0.005
Mg (incl Mn, Ni, Pb)	0.06
Mo	0.03
Na	0.12
N	0.73
P	0.04
Si	0.24
S	0.33
V	0.02
Zr	<0.10
H ₂ O	60.0

RADIONUCLIDES IN WET SLUDGE

Radionuclide	(pCi/g)
Ra	22
²³⁰ Th	5060
²³⁴ Th	<640
²²⁸ Th + ²³² Th	<450
²¹⁰ Pb, ²¹⁰ Po, ²²⁷ Ac	<750
²²⁸ Ra, ²³¹ Pa, ²³⁵ U	
²³⁸ U + ²³⁴ U	<270

Source: Kerr-McGee Nuclear Corporation Environmental Report for Sequoyah Facility Raffinate Sludge Disposal.

wastes are burned in an enclosed incinerator whose off-gases discharge to the boiler stack (FES 1975).

Uncontaminated noncombustible wastes are buried in accordance with the solid waste disposal requirements of Oklahoma (FES 1975).

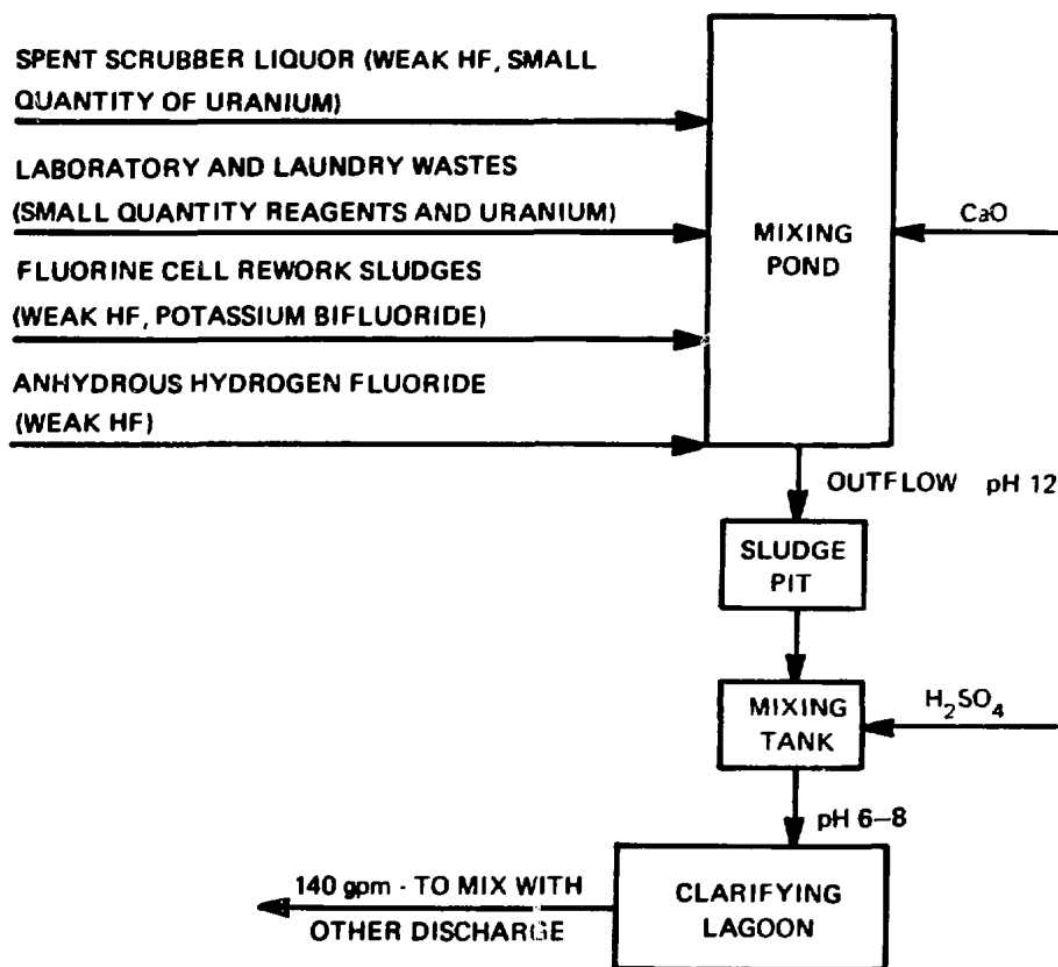


Fig. III-16. Liquid discharge treatment system for fluorine-containing wastes.

Radioactive wastes, such as scrapped equipment, gloves, respirators, and other contaminated solids, were buried on-site at a depth of at least 4 ft. Through June 1974, these wastes contained a total of 370 kg of natural uranium. These wastes are currently being stored.* Contaminated drums are being accumulated for disposal through a licensed scrap dealer (FES 1975).

D. Inadvertent Releases Involving Wastes and Effluents

1. Operational

From time to time, there will be small vent releases of process chemicals because of over-pressurizing, seal failure, loss of power, plant cleanup and repair operations, process problems, etc. There are no data available

as to frequency, rate of release, and types of release (FES 1975).

2. Releases from Pond Operations

In 1971, some lime and calcium fluoride were transferred from the fluoride sludge pit to the raffinate pond. Subsequent air drying and wind dispersion of a portion of this material resulted in above-average fluoride concentrations in some areas at the site. No cattle are allowed to graze in this region of dispersion (FES 1975).

The raffinate ponds are located near the river. It has been estimated that 14 million gallons (52 990 m³) of raffinate could be discharged to the river in the worst possible accident. Ammonia, nitrates, and organics in the raffinate could conceivably cause localized fish kills. Approximately 0.2 Ci of ²²⁶Ra, 0.09 Ci of ²³⁸Th, and 7700 kg of uranium might be discharged to the river (FES 1975).

*This information provided by William Nixon, NRC, April 1981.

3. Releases Caused by Rupture of Ducts and Piping Carrying Process Streams

Other types of accidents involving a discharge would be for a liquid-transfer line to break, discharging untreated waste. A gas transfer line, such as the duct for HF, hydrogen, or off-gases from the reduction unit to the combustion system, could also break, discharging untreated gases to the ambient air.

4. Failure of Effluent and Waste Treatment Equipment

Inadvertent releases could also occur if any dust collection equipment developed failures that resulted in channeling the gases around the collection device. Inadvertent releases of HF would result if (1) parts of the water scrubber became plugged, (2) there was a decrease in the liquid flow through the scrubber, or (3) the mist eliminator was damaged.

There appear to be no incidents or data available on releases caused by these types of treatment equipment failures.

Another inadvertent release could occur if the slaked lime feeder failed on the CaF_2 precipitation ponds. Depending on how long the condition existed, excess HF could be discharged to the river. Table III-9 indicates maximum levels of contaminants sampled in this discharge; this table indicates that over the reported sampling period, no major treatment failures occurred.

5. Transportation

No radioactive wastes have ever been transported off-site. Thus, possible public transportation accidents would only involve incoming concentrate and non-radioactive materials such as HF and ammonia, unless the State of New Mexico accepts the proposal for raffinate sludge disposal on a tailings pile, or unless in later years, other radionuclide-bearing waste is shipped off-site.

E. Long-Term Releases

Long-term releases of waste could occur from

- (1) subsurface movement of buried wastes (saturated or unsaturated flow),
- (2) man-caused disturbance of burial areas,

- (3) natural erosion (such as gully erosion or movement of the river to the burial area) exposing wastes,
- (4) animal-caused disturbance of burial areas,
- (5) plant root penetration of burial sites, and
- (6) radon diffusion through soils.

The burial areas must retain their integrity essentially "forever" if long-term releases are to be minimized.

The probability of long-term containment will depend on the final treatment/disposal of the presently generated uranium containing wastes and the raffinate and CaF_2 treatment sludges and future land use at the on-site burial ground.

F. Recommendations

To obtain a better data base for assessment of the Kerr-McGee UF_6 plant, the following projects should be undertaken.

- (1) Mass balance determinations for all materials entering the plant,
- (2) monitoring of nonroutine releases and fugitive emissions,
- (3) independent routine stack sampling of HF releases and oxides of nitrogen releases and seasonal fluoride and nitrate compound concentrations in surrounding soils and plants,
- (4) further environmental studies of the effects of the liquid discharge on the adjacent waterways,
- (5) routine sampling for U_{nat} , ^{226}Ra , and ^{230}Th in ambient air, water, and soils, including the respirable and soluble fractions in air, at locations determined from modeling of dispersion of stack and fugitive emissions to be locations of possible maximum concentration,
- (6) in-depth studies of long-term effects, which may result from routine emissions,
- (7) determination of possible long-term buildup of ^{230}Th and other contaminants on fields receiving raffinate decantate,
- (8) determination of the influence of change in operating conditions on plant discharges (for example, NO_x emission appears to depend on such factors as feed, temperature, and strength of acid in digestion circuit, operation of nitric acid absorbers, etc.),

- (9) determination of the content of raffinate sludges and the safety aspects of transport of these,
- (10) determination of the proper disposal of solid radioactive wastes now stored on-site,
- (11) determination of the content of CaF_2 -containing sludges,
- (12) determination of the adequacy of proposed sludge (both CaF_2 -containing and raffinate) disposal as to long-term effects,
- (13) determination of the contaminants in the condensed sulfur and suitable disposal techniques, and
- (14) determination of the possible long-term fate of wastes presently buried on-site, and
- (15) hydrotesting of any underground waste lines to ensure that pipes are not leaking.

REFERENCES

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Discharge Monitoring Report, NPDES, submitted to US Environmental Protection Agency by Kerr-McGee Nuclear Corp., received by EPA October 31, 1980.

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Radioactivity in Gaseous and Liquid Effluents—letter to Glen D. Brown, NRC, from W. J. Shelley, Kerr-McGee, September 26, 1980.

Safety Evaluation Report by the Division of Fuel Cycle and Material Safety Related to the Source Material License Renewal of the Kerr-McGee Nuclear Corporation, Docket No. 40-8027 (1977).

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

A. Effluent/Waste Characterization

Although the UF_6 facilities have extensive waste treatment systems in operation, airborne radioactive releases from the facilities are larger than at fuel fabrication facilities (Table IV-1). Of particular concern are the radionuclides ^{230}Th and ^{226}Ra , which occur as impurities in the concentrate feed to the UF_6 conversion facilities. (The impurities, of course, are not present in fuel fabrication feed.)

In addition to radionuclides, waste streams (air, water, and solid) contain fluoride compounds, nitrogen compounds (composition and quantity somewhat dependent on whether the wet or dry process is used), organic compounds (again dependent upon process used), and trace elements found in the concentrate, such as molybdenum, vanadium, and arsenic, all of which may adversely affect the environment (depending on concentration, compound, etc.).

B. Plant Circuit Design and Waste Treatment

Because each UF_6 facility is very different, specific recommendations have been included in Chapters II and III. When a new UF_6 facility is built in the US, a detailed comparison of resource requirements, effluent/waste generation, safety, etc., should be made for the wet vs dry process.

TABLE IV-1

A SUMMARY OF THE RELEASE OF RADIOACTIVITY IN THE ENVIRONMENT

	Air Effluents ($\mu\text{Ci/yr}$)		Liquid Effluent (Ci/yr)	
	EIA	Reported (7/76-6/77)	EIA	Reported
Fuel Fabrication Plants				
1. Westinghouse (Columbia, S.C.)	3700	3010	0.319	0.116
2. General Electric (Wilmington, N.C.)	2079	2520	0.300	0.760
3. Combustion Engineering (Hematite, Mo.)	409	467	0.026	0.026
4. Babcock & Wilcox (CNFP) (Lynchburg, Va.)	6	6	a	a
5. Exxon Nuclear Co. (Richland, Wash.)	100	12	a	a
6. B&W Apollo (Apollo, Pa.)	695	695 (1/78-6/78)	3.5	3.5
7. Combustion Engineering (Windsor, Conn.)	20	11	a	a
UF₆ Conversion Plants				
1. Allied Chemical Corp. (Metropolis, Ill.)	320 000	310 000	1.68	2.19
2. Kerr-McGee (Sequoyah, Okla.)	45 717	46 400	1.8	1.2

*Insignificant.

Source: Internal Summary, Nuclear Regulatory Commission, Washington, D.C., 1979.

C. Recommendations for Monitoring

Although the publically available data on routine operation identifies no major areas of serious concern, further publically available data, obtained by an independent monitoring group, on the size, distribution, and solubility of the various radionuclides in the ambient air at locations determined by modeling of dispersion of stack and fugitive emissions would aid in assessment. In addition, published concentrations of fluoride and nitro-

gen compounds and trace elements in ambient air, soils, plants, surface and ground water, and foraging animals would aid in evaluation of these facilities for the effects of nonradioactive emissions and waste disposal practices.

Nonroutine releases, which occur during process upsets, equipment malfunction, maintenance, etc., and releases that occur because of fugitive emissions, need additional monitoring and evaluation. No attempt was made to define releases and wastes generated during decontamination and decommissioning. These also need further study.

D. Recommendations for Studies of Long-Term Aspects

The long-term aspects of the following need further study.

(1) Buildup of radionuclides and other contaminants in surrounding soils and waters,

(2) disposal of solid wastes and sludges, including nonradioactive sludge and solid wastes, and

(3) effects caused by wastes presently disposed of at the site.

APPENDIX*

AQUATIC BIOTA IN THE ILLINOIS RIVER NEAR THE EFFLUENT DISCHARGE POINT

*This information provided by Kerr-McGee Nuclear.

Benthic Macroinvertebrate Monitoring Program for 1980 in the Illinois River Adjacent to the Effluent Outfall of the Sequoyah Facility

The 1980 monitoring program ended with the fall sampling period (October 25—December 6). This period corresponds with two previous sampling periods: fall of 1978 and fall of 1979. The fall is a well established sampling period in this program and should be continued in future monitoring. It is also an ideal period because it does not coincide with high probabilities of vandalism (fishing pressure).

The results from the upstream station, which corresponds with Transect 6B of the initial monitoring program, are as follows: number of species, 18; number of individuals, 559; and diversity index, 2.58. The results from the downstream station, which is near Transect 1B of the initial monitoring program, are: number of species, 18; number of individuals, 962; and diversity index, 1.14. The results from the effluent mouth are: number of species, 32; number of individuals, 343; and diversity index, 2.16.

This data, compared with the 1978 and 1979 fall sampling periods, show a striking difference for all parameters (Table I). The upstream station showed the greatest degree of difference with the previous two years, and the effluent station showed the minimum degree of difference. The low values for all three parameters for the upper Illinois River suggest that the water below Tenkiller Lake is of lower quality than the two previous falls.

TABLE I
COMPARISON OF THREE CONSECUTIVE FALL
SAMPLING PERIODS
1978-1980

Station	Number of Species	Number of Individuals	\bar{d}
U (6B) Fall 78	35	2294	3.09
U (6B) Fall 79	40	2484	3.11
U (6B) Fall 80	18	599	2.58
D (1B) Fall 78	24	962	3.05
D (1B) Fall 79	40	1687	2.85
D (1B) Fall 80	18	962	1.14
EM Fall 78	29	783	4.08
EM Fall 79	35	403	2.52
EM Fall 80	32	343	2.16

U - upstream station.
D - downstream station.
EM - effluent mouth.

**LIST OF SPECIES AND NUMBER OF INDIVIDUAL ORGANISMS AT
STATIONS IN THE ILLINOIS RIVER, OCTOBER 26—DECEMBER 6
(Pooled Samples)**

Species List	Upstream	Downstream	Effluent Mouth
Coelenterata			
<i>Hydra</i> sp.	17	4	6
Annelida			
<i>Nais</i> sp.	30	25	22
<i>Dero</i> sp.	7	9	-
<i>Stylaria lacustris</i>	5	-	3
Arthropoda			
Amphipoda			
<i>Gammarus</i> sp.	-	-	1
Insecta			
Coleoptera			
<i>Oreodytes</i> sp.	-	-	2
<i>Deronectes</i> sp.	-	-	1
Odonata			
Unidentified Coenagrionidae	-	-	3
Ephemeroptera			
<i>Caenis</i> sp.	-	-	2
<i>Stenacron</i> sp.	1	1	-
Trichoptera			
<i>Hydroptilla</i> sp.	1	-	4
Diptera			
<i>Glyptotendipes</i> sp.	255	808	235
<i>Glyptotendipes senilis</i>	48	4	2
<i>Cladotanytarsus</i> sp.	154	2	24
<i>Trisocladius</i> sp.	29	1	2
<i>Parachironomus</i> sp.	3	3	2
<i>Chironomus</i> sp.	1	33	1
<i>Potthastia</i> sp.	4	-	-
<i>Cricotopus</i> sp. C	17	-	2
<i>Cricotopus</i> sp. C	8	-	3
<i>Rheotanytarsus</i> sp.	7	-	5
<i>Einfeldia</i> sp.	-	29	-
<i>Psectrocladius</i> sp. B	-	13	1
<i>Dicrotendipes nervosus</i>	-	5	1
<i>Micropectra</i> sp.	-	1	3
<i>Conchapelopia</i> sp.	-	1	2
<i>Ablabesmyia mallochii</i>	-	1	6
<i>Polypedium</i> sp.	-	-	1
<i>Tribelos</i> sp.	-	-	2
<i>Ablabesmyia ornata</i>	-	-	1
<i>Tanytarsus</i> sp.	-	-	2
<i>Labrundinia</i> sp.	-	-	1
<i>Dicrotendipes modestus</i>	-	-	1
Number of species	18	18	32
Number of individuals	599	962	343
Mean species diversity \bar{d}	2.58	1.14	2.16

Source: Kerr-McGee.